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THE MODERN GAS TRACTOR
ITS CONSTRUCTION, OPERATION, APPLICATION AND REPAIR

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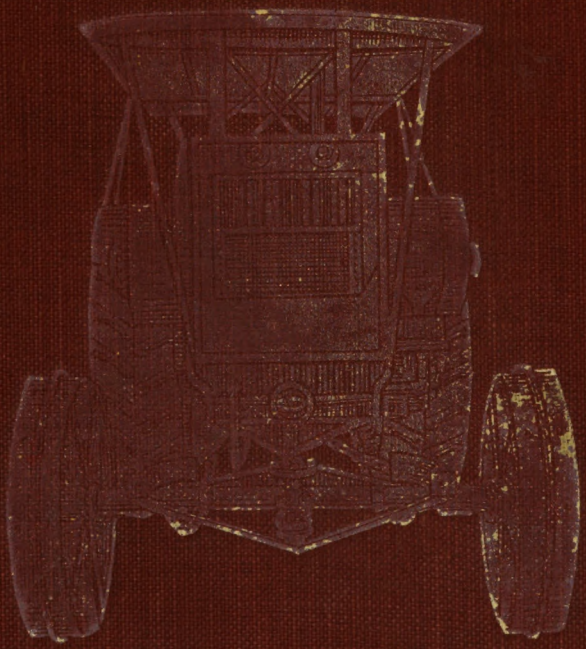

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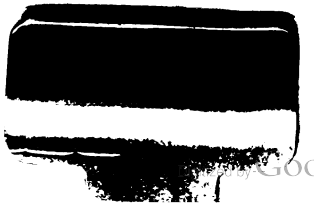

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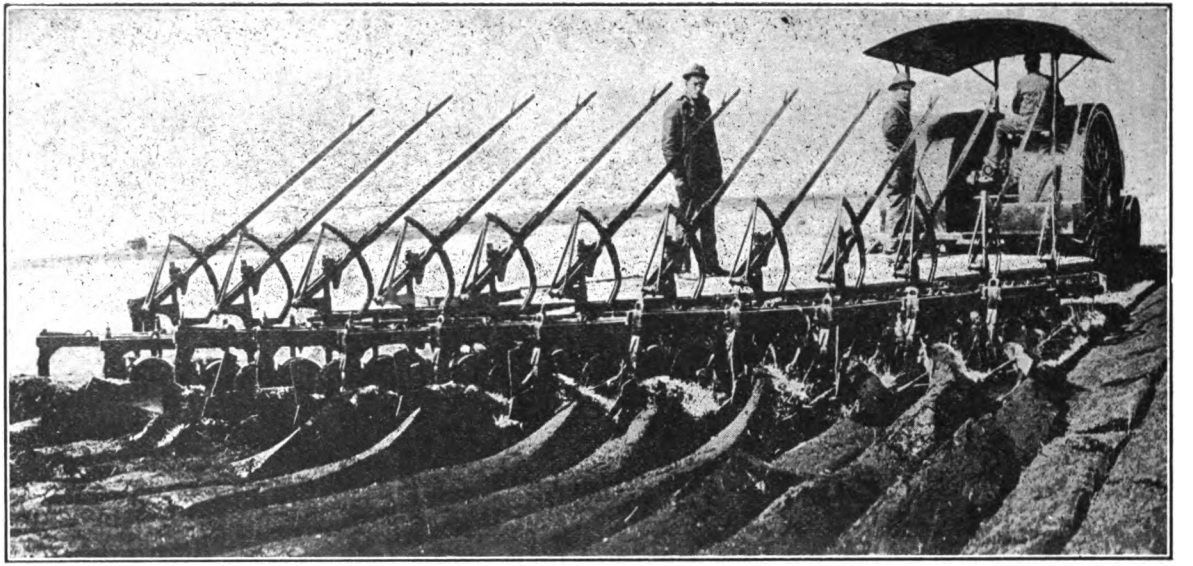

The Tractor and the Plough, an Invincible Twentieth Century Combination.

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THE

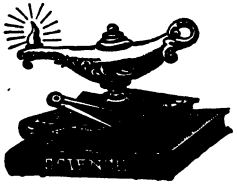
MODERN GAS TRACTOR

Its Construction, Utility, Operation and Repair

A PRACTICAL TREATISE

Covering Every Branch of Up-to-Date Gas Tractor Engineering, Driving and Maintenance in a Non-Technical Manner. Considers Fully All Types of Power Plants and Their Components, Methods of Drive and Speed Changing Mechanisms. Describes Design and Construction of All Parts, Their Installation and Adjustment, As Well As Practical Application of Tractors in the Field.

By VICTOR W. PAGÉ, M.S.A.E.
Author of the "Modern Gasoline Automobile," etc., etc.



THIRD EDITION, REVISED AND ENLARGED

Invaluable to the Student, Farmer, Machinist, Blacksmith, Implement Dealer, Rancher and All Others Wishing Reliable Information on Gas Motor Propelled Traction Engines and Their Use

OVER 225 ILLUSTRATIONS AND FOLDING PLATES

NEW YORK
THE NORMAN W. HENLEY PUBLISHING COMPANY
2 WEST 45TH STREET
1918

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COMPOSITION, ELECTROTYPING AND PRESSWORK
BY BRAUNWORTH & CO., BROOKLYN, N. Y.

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PREFACE

The internal combustion motor has been responsible for many developments in the industrial sciences, but its greatest achievement has been the promotion of economical and efficient transportation. The improvements in the design of the modern gas tractor, which have made it an entirely practical and satisfactory source of power, have also opened up fields where it can be used to advantage and profit that would have been impossible with steam traction engines formerly the vogue, or other forms of power.

It is not the writer's intention to underestimate the advantages and utility of the steam tractor; it has and still is performing work of great value. The gas tractor, however, in its modern forms, is able to accomplish everything the steam propelled type can do, and has important advantages the other construction does not possess. It does not require services of a skilled engineer to operate, it has a wider range of action, is more independent of fuel and water supply in that it does not consume much liquid in cooling, and is more economical of fuel because it utilizes a larger proportion of the potential energy or heat units of the combustible by burning it directly in the cylinders.

The many advantages of the internal combustion or gas motor have made it the recognized prime mover where economical operation and minimum attendance is required, so it is but natural that it should reign supreme in the field of general transportation.

This treatise is intended as a guide for the average

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farmer and mechanic. It is not presented as a technical or engineering exposition, yet endeavor has been made to present some principles of design in a simple manner so they may be readily understood by those without technical knowledge. The object of the writer has been to discuss the engineering features of various constructions only with a view of familiarizing the reader with the salient points of design, so the advantages of the various systems of construction may be intelligently analyzed in order that the mechanism best adapted to individual requirements be selected.

There is a large field to select from. Tractors may be obtained ranging from motor propelled lawn mowers or ploughs capable of use as light traction power to the heavier constructions employed in tilling the broad township farms of the Middle West. Special designs have been evolved applicable to use in swamps or rice fields of the South or the snow bound lumber camps of the extreme North where no other form of power can work, so the range of utility of the gas tractor is practically unlimited.

The chapters on maintenance and repair should be of special value, while the various applications described cannot fail to offer the up-to-date farmer some suggestions whereby he can improve his present methods and save money. The student is always interested in construction and design, the practical man wishes more specific information. This treatise is intended to bridge the gap existing between the purely technical work and the manufacturers' instruction book dealing with one specific construction. If it has accomplished this, the writer will feel amply repaid for the time and labor expended on its compilation.

June, 1918 THE AUTHOR.

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ANNOUNCEMENT

The Author desires to acknowledge his appreciation of the valuable assistance accorded him by many of the leading firms in the field of Tractor Manufacture and associated industries. Many of the illustrations have been furnished by progressive manufacturers whose publicity efforts and excellent product have done so much to popularize the gasoline farm tractor, and many valuable suggestions regarding treatment of the subject have been obtained from the literature so kindly supplied by them. The following list of firms contributed materially to making this work complete and of value:

Rumely Products Company, La Porte, Ind.
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Pioneer Tractor Manufacturing Co., Winona, Minn.
Buckeye Manufacturing Company, Anderson, Ind.
The Russell & Co., Massillon, Ohio.
Auto Tractor Company, Chicago, Ill.

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THE MODERN GAS TRACTOR

CHAPTER I.

THE SCOPE, ADVANTAGES AND APPLICATION OF POWER TRACTION.

Influence of Mechanical Power on the Arts—Application of Power in Agriculture—Advantages of Power Traction—Comparison Between Work of Horse and Tractor—Thermal Efficiency of Horse—Tractor Furnishes Power for Various Farm Machines—Economical Aspect of Power Traction—Analysis of Requirements of Ideal Tractor—Practical Prime Movers—Comparing Steam and Gas Power from a Practical Point of View—Efficiency of Steam and Gas Power—Why Gas Tractors Are Most Popular.

Influence of Mechanical Power on the Arts.—The discovery of the expansive power of steam and the development of the practical steam engine by Watt was the inception of the era of supremacy of mechanical power and the decline of animal energy in the mechanical arts. The first steam engine was devised to draw water out of mines with greater celerity than prevailed with animal power, the only source of work available when natural forces, such as wind or falling water could not be used and though crude in form, it was not long before it had conclusively demonstrated its superiority as a prime mover and was generally used to replace animal power in the industrial establishments and workshops of the day.

When the steam engine had been developed still further, other inventors sought to apply it to the wide field

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of transportation. Early in the 19th century the steamboat contrived by Robert Fulton proved without question that navigation by mechanical power was possible, and a little later, road vehicles were devised that ran without horses. The opposition of the ignorant public prevented further development and some countries, notably England, passed laws excluding such self-pro-

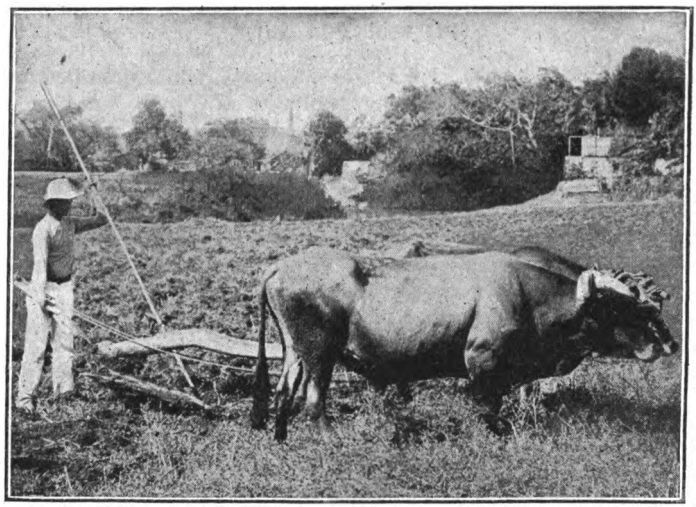

FIG. 1.—The Method of Ploughing in Vogue for Over 5,000 Years. Animal Drawn Single Furrow Plough.

pelling vehicles from the highways. Ignorance has always been a bar to progress, and thus the antipathy of an uneducated populace delayed the development of the modern automobile by over half a century.

While the steam engine and other forms of prime movers soon displaced horse and human power in the field of mechanical engineering and general manufacturing, ani-

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mal power has remained for years supreme in the oldest and most important industry of mankind, agriculture. In most countries it is the horse, ass or ox that is used for drawing the ploughs and other machines utilized for tilling the soil. In India and parts of Africa the elephant is used, in Asia the camel furnishes power. Domesticated buffalo, reindeer, or dogs serve as motive power in other localities while the pioneer Doukhabor farmer of Canada, when too poor to purchase horseflesh harnessed ten or twelve women to the plough and thus tilled the virgin soil that soon gave him a competence.

Application of Power in Agriculture.—Agriculture is the basis of any country's prosperity. It is the most important of the occupations of man because it furnishes the majority of the foodstuffs that sustain life. A country that cannot grow enough food for its population is always in grave danger, and no matter how large its other resources may be, it is always at the mercy of those states that are able to feed their people. Of late years, a number of conditions have served to direct public interest to the farmer and the important bearing his work bears to the general welfare of the people. The increasing cost of living, the high prices for the bare necessities of life demands careful consideration and scientific application of principles that will increase the farmer's efficiency. It is more important that the cost of producing the food of man be reduced than that of any other thing. It takes good food and plenty of it to conserve human and animal life and efficiency.

Just as mechanical power increased production and reduced cost of our manufactured products to such an extent that the luxuries of kings of but a century ago are available to the poorest workman of to-day, so its general application to the farmer's work will increase

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the productiveness of his fields. It will give him more time for the intelligent direction of his activities by reducing the daily grind of incessant toil heretofore his lot; and increase his wealth and purchasing power and thus benefit the public at large in many ways. The possibilities of expansion of our already large agricultural industry by application of mechanical power to the fields,

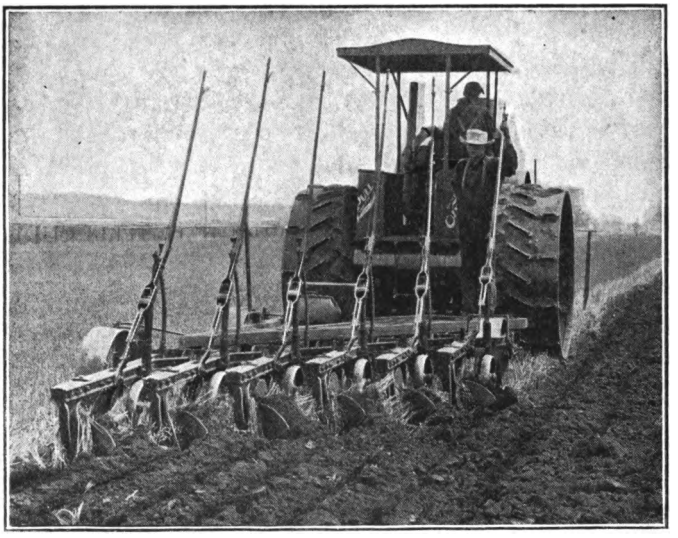

Fig. 2.—The Modern Method of Soil Tillage. Mechanical Power Furnished by Gas Tractor Pulls Six Ploughs at Once. Some Tractors Powerful Enough to Make Fourteen Furrows at a Time.

workshop and even households of our rural population can be adequately grasped only by a study of sociology and economics that is obviously not within the scope of a mechanical treatise.

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Advantages of Power Traction.—There is no point about the farm where power is more necessary than in the fields, and it is said that more energy is spent in plowing annually than in the combined factories of the world during the same period. The earliest plow was a crotched stick and served to till the ground for the first of our primitive ancestors who conceived the idea that breaking the ground was the first step and one of the most important that had bearing upon the growth of the seed sowed therein. Plowing has always demanded more expenditure of energy and time than all other lines of farm work combined. History records that the Chinese Emperor Shen Neng who assumed the sceptre nearly 3,000 years before the beginning of the Christian era, "first fashioned timber into plows." For over 5,000 years ploughing has been done by animal power and the feet of the larger majority of our farmers are still in the furrow, their arms still control and guide the plough.

The call first came for power to pull the plough, to make many furrows in the time usually taken to make one. The earth must be ploughed at a certain time, and under sharply defined conditions. To violate any of the rules, either of time or thoroughness of tillage makes material difference in the quality and quantity of the crops. The amount of land tilled depended upon the equipment of the farmer and the endurance of his employees and horses. At best, the area ploughed was generally but a small percentage of the ground available for cultivation. The crops were limited and the productive ability of the farm was relatively low in comparison to what power makes possible.

The first steam ploughing engine is credited to J. W. Fawkes, and was built in 1858. It drew eight plows in prairie sod at the rate of three miles per hour. The first

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gasoline tractor was placed on the market in 1893 but could not compare with the steam tractor because of the crudeness of the gasoline engine of that period. It was not until 1903 that the gas tractor became a commercial success. The development of the practical internal combustion tractor was even more important than the invention of the mechanical reaper and binder or the threshing machine. It gave the agricultural industry the power that was needed, and its advent marks the greatest jump of progress in the history of agriculture. From its advent, barely a decade ago, the story has been one of steady progress. Difficulties have been gradually eliminated and to-day one may say that many of the tractors sold have reached a high efficiency, while all made by reputable manufacturers are practical and capable of wide application. It is estimated that over seventy-five firms are offering gas tractors of all varieties and the sales at the present time run well up into the thousands yearly. They have been shipped to all parts of the civilized world, yet the industry is but in its infancy.

Power traction is superior to animal energy because it will do more work in a given time at less expense than possible with any other traction means. It can be adapted to tasks that cannot be accomplished by any other power and it is always ready for work. When intelligently managed its operating cost is so much less than that of horses necessary to do the same work or the amount of work done in a given time is so much greater than possible with any other form of power of the same cost that its merits are apparent to any one able to analyze its performance.

Comparing Work of Horse and Tractor.—A brief summing up of the comparative merits of horse-power

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and mechanical energy show clearly the reason why the animal is doomed to give way to the gas tractor on everything except, perhaps, very small farms, and even in this field of application, some of the lighter tractors are available and will do anything the animal can and much work that the horse cannot be made to perform. In the prime advantage of economy, both in time and money, the tractor is cheaper by a wide margin. A tractor works in any kind of weather without fatigue. The horse is affected by extremes of temperature, either hot or cold. The horse is subject to all ills that flesh is heir to, if the animal breaks down, nature is the only possible repairman and it works slowly.

The tractor is machinery, any one of average intelligence can replace worn or broken parts with but slight delay. The tractor feels neither heat or cold. It will work equally well in the torrid heat of summer or the icy blasts of winter. A tractor can be housed cheaper than the number of horses needed to do the same work can, it requires no care and does not eat when not in use as horses do. Its days work is limited only by the number of hours in the day and the endurance of its operators. Its working period is not measured by periods of 6, 8, or 10 hours, with frequent stops for rest. The tractor will work 24 hours per day, and pull as strong the last minute of the period as when first started.

To be convinced of the relative value of horse and mechanical power, one can compare the original cost of any tractor with the first cost of a sufficient number of horses to do an equal amount of work. The comparison favors the tractor. If one compares the maintenance cost of the two outfits, the machine is overwhelmingly superior to the animal. Compare the amount of work

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accomplished by them and its approximate cost, you will soon appreciate the value of the tractor. A farmer cannot afford to feed and house the number of horses necessary to do the work a 50 or 60 horse-power tractor can.

Fig. 3.—A Man Easily Carries Fuel and Water Enough for an Extended Period of Operation When Gas Engine is Used for Power.

Thermal Efficiency of the Horse.—The horse may be considered as a motor in the sense that it utilizes the heat units contained in its food, which represents the fuel that is burnt in the cylinder of the gasoline engine or under the steam boiler. The ratio between the energy given out by the animal and the amount of fuel consumed respresents the thermal efficiency, or utilization of heat relative to work done. There are different methods of com-

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paring the efficiency of the horse and the inanimate engine.

The engineer considers the ratio of the heat units delivered by the motor as useful work to the total heat units in the fuel supply. The student of animal physiology first determines the number of digestible elements contained in a given food and considers this the fuel value of the feed. It is said that 30 per cent. of the fuel value of food is lost in the energy expended by the animal in chewing and digesting it. In addition to a food having a fuel value it also has a maintenance value. The amount of external work that can be obtained when the animal is given a certain definite amount of food is termed the "production value." Even when the horse is working a certain proportion of energy is being consumed in moving its body and as it is able to deliver work only when in motion the thermal efficiency of the horse is very low, being given as not more than 6 to 10 per cent. This is exceeded by most internal combustion tractors. Experts of the U. S. Department of Agriculture have obtained an efficiency of 20 per cent. under laboratory conditions. While this may be true of scientifically fed animals under careful supervision, the horses that work under actual farm conditions have a much lower efficiency.

Many experiments have been made to determine the actual power of a horse. James Watt, the inventor of the steam engine, placed the working power of a 1,500-pound animal as the ability to lift 33,000 pounds to a height of one foot each minute or 550 pounds to the same height each second. This originated the term "horse-power" which has been used in the mechanical world ever since these classical experiments were made as a unit for the measurement of power delivered from, or consumed by mechanical devices.

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Recent experiments seem to indicate that the work performed by the average animal approximates 22,000 foot-pounds per minute, or two-thirds of a horse-power. Other investigators declare that the average horse will deliver three-quarters of an actual horse-power. The working ability of a horse is measured by its pulling power which is called "draft" and it is on this basis that traction engines are compared to horse flesh. The pulling power of the animal is given at one-tenth of its weight when working continuously ten hours each day pulling some object at the rate of 2½ miles per hour. Under these conditions a 1,200-pound horse will develop but eight-tenths of a horse-power and a 1,500-pound animal one horse-power.

For short periods the horse may exert a maximum draft of about one-half its weight but obviously this work cannot be done continuously and the amount of energy can be exerted for but a short time without injury. The pulling power of the average plough horse is given as 150 pounds. One horse-power is equal to a draft of 187.5 pounds at the rate of two miles per hour. It is evident that no matter whether one considers the horse from a practical or scientific point of view that mechanical power shows a marked advantage over animal energy.

Tractor Furnishes Power for Various Farm Machines.—We have seen that the horse can do its best work only when pulling a load. If used for power through the medium of a tread-mill, for operating various forms of machines, the efficiency is still lower and the ratio between useful work obtained and amount of food consumed is such that it is not economical to utilize the animal in this way. The usefulness of a tractor is more varied than that of any other farm machine. It

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is not only the most economical power for ploughing but it operates with equal economy all the machines and appliances necessary for raising and harvesting crops. These include disk harrows, seeders, drills, packers, binders, etc.

It can be used for hauling grain to the elevator, pulling stumps and hauling all kinds of lumber and supplies to

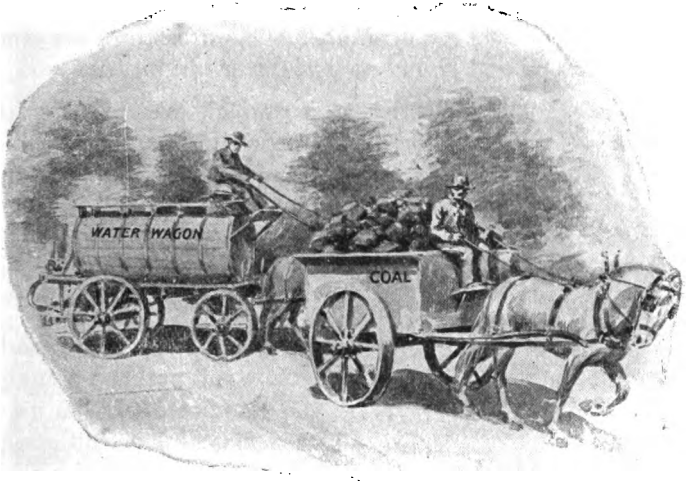

Fig. 4.—The Caravan Needed to Keep a Steam Traction Engine Supplied With Fuel and Water is a Large Item in Operating Costs.

the farm. Most tractors can be used for stationary power and a belt may be run from the pulley provided for the purpose to operate threshers, shellers, shredders, pumps, sawing outfits and any other form of machine needing power. It has sufficient power to run a large number of machines at a time if the main drive is connected to a line shaft which will turn a number of machines in unison.

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The gasoline traction engine is assuming increased importance in contracting and road construction work. Operating expenses of a tractor are materially less than when animals are employed because the amount of help needed is reduced to a minimum. One man easily does the work of three or four. The fact that it requires no attention and consumes no fuel when not in use is an advantage not possessed by animal power. Horses must be wintered and for a number of months they are consuming food and giving no useful work in return.

The amount of land that is now given over to cultivation of food for horses and other draft animals could be just as well used in raising the food elements needed by the human race. The tractor consumes nothing that has any definite food value or that can be utilized by the people to better advantage than it is as fuel in producing power.

The tractor knows no seasons and on any farm, work can be found for it at all times. It will pull the ploughs and drills in the spring; in the summer it can be used for making roads and hauling supplies; in the fall it can operate a binder or thresher; in the winter it may be used as power for a sawing outfit, or for running a husker, shredder, or sheller. Between seasons it will do heavy hauling, pump water, cut ensilage, operate grinding mills, haul manure, bale hay and dig ditches. The large range of use to which the average tractor can be adapted and the relatively slight cost for its maintenance cannot fail to impress the economical owners of farms who are conducting them on a business basis and to whom great efficiency and lower cost of production means vastly increased profits.

Economical Aspect of Power Traction.—The

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farmer who is just beginning to realize that power traction offers many advantages is desirous of ascertaining just what the average tractor will accomplish for him and at what cost. He is not satisfied to read general claims of desirability, adaptability or economy. He wishes definite figures. He desires to know how much better and how much cheaper the farm tractor can do his work than the same amount can be accomplished with horses and farm hands.

One of the great difficulties of farming on a large scale by old methods exists in the fact that certain work must be accomplished at a definite time. The ploughing, the seeding, harvesting and threshing must all be done during definite periods. This work must be in progress while climatic and weather conditions are right. It is at this time that the capacity and endurance of mechanical power is emphasized and the wonderful superiority of the tractor over horses and farm hands made evident.

The value of early fall ploughing is generally accepted, as under this treatment the weeds are turned under the sod while still green and the decaying vegetable matter forms an invaluable fertilizer. The weeds all bear seed which would sprout in the spring under ordinary circumstances. Ploughing brings these near the surface and as they commence their growth before winter comes the frosts soon put an end to this objectionable vegetable growth. The result is a field free from weeds for the next grain crop.

The agriculturist who uses a tractor for threshing is able to do it as soon as the grain is ready. If this is interrupted by rain the tractor can be utilized for ploughing and under these circumstances many farmers have finished their fall ploughing almost as soon as they have completed their threshing operation.

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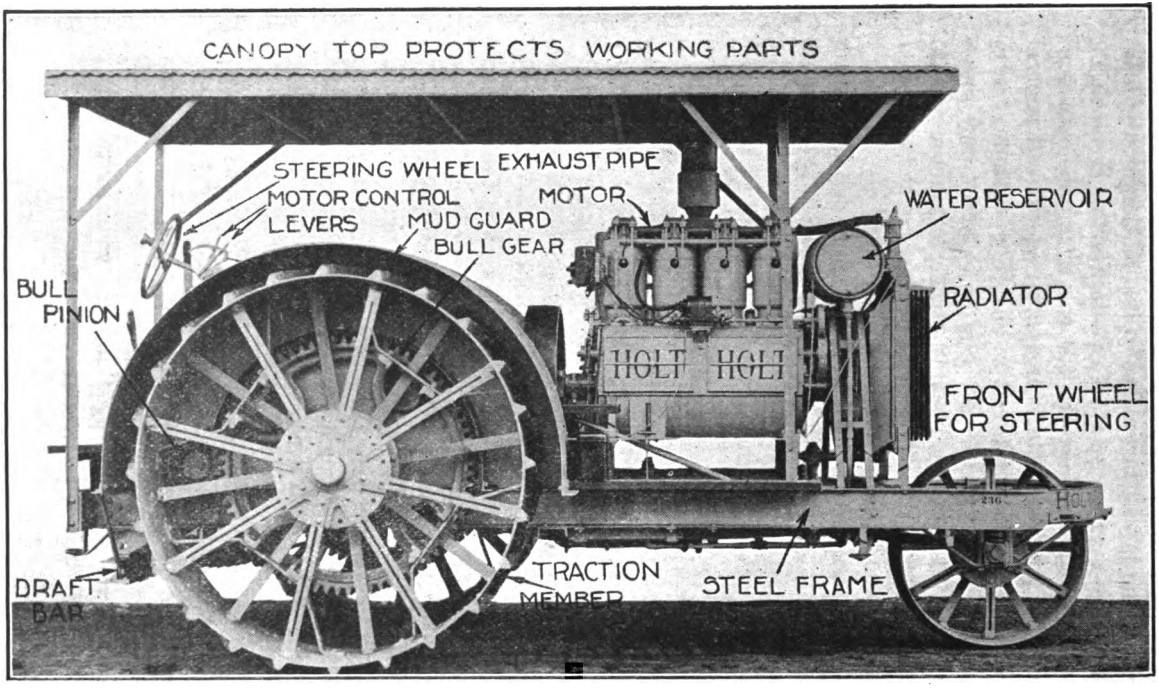

FIG. 5.—Side View of Holt Illinois Traction Engine, Showing Location of Important Parts.

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Another work that requires to be done promptly is harvesting. This is usually done in very hot weather, and both horses and men suffer from working in the excessive heat. If one has a large area under cultivation and no men are available for the harvesting, it will not take much inclement weather to destroy grain of a value greater than that of a tractor that might have harvested the entire crop at the proper time.

A gas tractor not only effects a striking economy but it multiplies the efficiency of every piece of machinery or implement on the farm not operated by human power. No agriculturist, worthy of the name, will question that the self-binder is a great invention, as are also the drill, mowing machine, the disk or toothed harrow and the gang-plough. The development of modern farming is due to all of these implements, yet each is limited in usefulness by the cost of the power required to operate it. Any of these implements attached to the powerful, quickly moving and economically operated gas tractor has a greatly increased value over that possessed when only the more expensive and less efficient horse traction is available. The following figures are given by a prominent tractor manufacturer, the Gas Traction Company, as the average cost under ordinary conditions for the various tasks enumerated.

PLOUGHING

Thirty acres considered the average day's work.

One engineer and board, $75.00 monthly	$3.00
Forty-five gallons gasoline at 16 cents	7.20
Lubricating oil and grease	1.50
	$11.70
Cost per acre	.39

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BREAKING.

Twenty-five acres considered the average day's work.

One engineer and board, $75.00 monthly	$3.00
Fifty gallons gasoline at 16 cents	8.00
Lubricating oil and grease	1.50
	$12.50
Cost per acre	.50

The point is emphasized that the above tables apply to average conditions and one must draw his own conclusions as to what can be accomplished in his specific

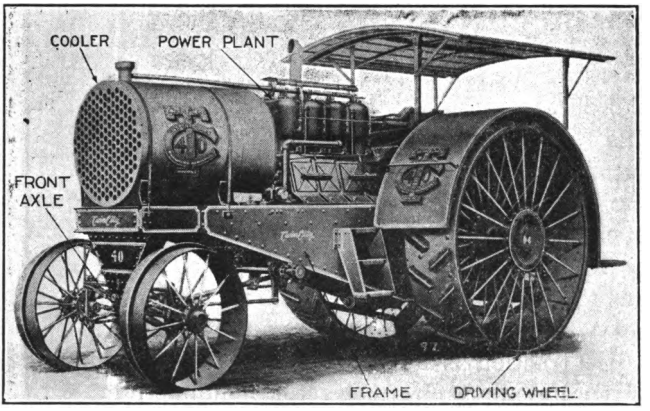

FIG. 6.—Typical Large Capacity Gas Tractor of Latest Approved Design, with Important Parts Clearly Shown.

case. In exceptionally heavy gumbo the average cost will be greater but in lighter sandy loam it will be easy to reduce the cost. In these tables depreciation and interest on the investment are not included because this is an uncertain quantity.

The big advantage of the gas tractor is realized in threshing. The average gas tractor of 25 to 30 horsepower will drive any make of separator and one engi-

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neer operates both power plant and threshing machine because he has no duties to occupy him after the tractor arrives at the destination. There is no steam pressure to keep up, no fuel to handle, no water gage to watch and no danger of fire around the engine due to sparks. The engine will run smoothly for hours without attention because it is automatically lubricated and the fuel supply is continuous as long as any remains in the tank.

The Gas Traction Company, in speaking of the use of the Big Four "30" in threshing, state, that this machine will drive a 36-inch separator of any standard make. The engineer is to run the separator, as well as the engine, two good pitchers being employed to feed the machine and four dump racks, with a man and team of horses for each to haul the bundles to the pitchers at the separator. The gas tractor, with the separator attached can quickly change its stand and keep near to the grain to be threshed. This makes a short haul for the teams bringing the bundles and requires fewer men and teams than a steam rig, threshing the same amount of grain. It is claimed that this small crew of seven men will easily thresh from 1,000 to 1,800 bushels per day, according to the character and weight of the grain. This may be done at a cost of labor, teams and fuel, as follows:

THRESHING.

One engineer's wages and board	$5.00
Two pitchers' wages and board	6.50
Four teams and men at $5.00 each	20.00
Thirty-five gallons gasoline at 16 cents	5.60
Lubricating oil	1.00
	$38.10

Average amount threshed of wheat, running 15 bushels per acre, 1,400 bushels. Cost of threshing a little less than 2¾ cents per bushel.

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If the gas tractor is suitable for the heavier work of ploughing and breaking, it is obvious that its capacity for the lighter form of traction work must be very great. The high wide wheels and the relatively light weight of the average tractor enable them to travel over the ground without sinking in or packing the soil. A tractor will draw any load where horses will draw it. Consequently the farmer need not keep horses eleven months to do one month's work. A 30 horse-power tractor, for example, will draw four 10-foot drills, six 8-foot disks, and all the harrows that can be conveniently hitched on. With four 10-foot drills and two 20-foot drags behind, two men can drill and drag from 100 to 150 acres per day at a cost under 25 cents per acre.

The great inventor, Thomas A. Edison, is credited with the following quotation: "An invention that will enable the farmer to harvest his crop cheaper, better and faster than heretofore, is worth $100,000,000." It is not difficult to arrange hitches to enable tractors to pull drills, drags, ploughs, or any other implement where the engine has a straight pull and a clear field. It was a more difficult matter, however, to perfect a hitch by which several binders could be drawn after the engine, the tractor running at the edge of the grain, and the binders, each cutting its full swath off at one side. There could not be any side draft, no running over uncut grain or bundles, and the natural side draft of the binders themselves must be overcome. At the present time various hitches have been perfected, so that a large number of binders of any size or make may be operated in connection with the average tractor.

The following summary shows in a broad general way a statement of what a representative tractor could do in volume of work and at what cost:

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VOLUME OF WORK.

Breaking, per day	20 to 40 acres
Stubble ploughing, per day	25 to 50 acres
Drilling and harrowing, per day	100 to 150 acres
Double-disking, per day	60 to 75 acres
Harvesting, per day	60 to 100 acres
Threshing wheat, per day	1,400 to 2,500 bushels

COST OF WORK.

Breaking	$0.50 to $0.75 per acre
Stubble ploughing	.40 to .50 per acre
Drilling and harrowing	.20 to .25 per acre
Double disking	.10 to .20 per acre
Harvesting (exclusive of twine)	.20 to .30 per acre
Threshing	.03 per bushel

The gasoline used is given as two gallons per acre while breaking prairie sod. Stubble ploughing consumes about 1½ gallons per acre. The engine will use but 35 gallons when threshing an entire day. In general the operating expense of a tractor, providing that work enough is at hand to keep it working to capacity, will be about one-third the operating expense of the number of horses necessary to do this same work. It will reduce the number of hired help needed by two-thirds, and if there are young people on the farm its value cannot be estimated easily, because it accomplishes the important result of converting an old-time humdrum and laborious occupation into an interesting up-to-date business.

Analysis of Requirements of Ideal Tractor.—The requirements of the ideal tractor can be summed up as follows: First, it should have universal adaptability, in order to be able to accomplish all kinds of belt or drawbar work, as it is only by having a machine that is applicable to a large variety of tasks that one can justify the investment needed to purchase a practical machine.

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FIG. 7.—The Lambert "Steel Hoof" Tractor, A Three Wheel Form Suitable for Orchard Cultivation and General Small Farm Work.

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It should be capable of operating every machine on the farm that requires power.

Second, it should have correct weight for the work it is to do and the proper arrangement of components. A logical distribution of weight is necessary to insure proper traction. If the machine is too heavy it will pack the soil and much power will be consumed in moving the huge mass over the ground. The factor of weight is

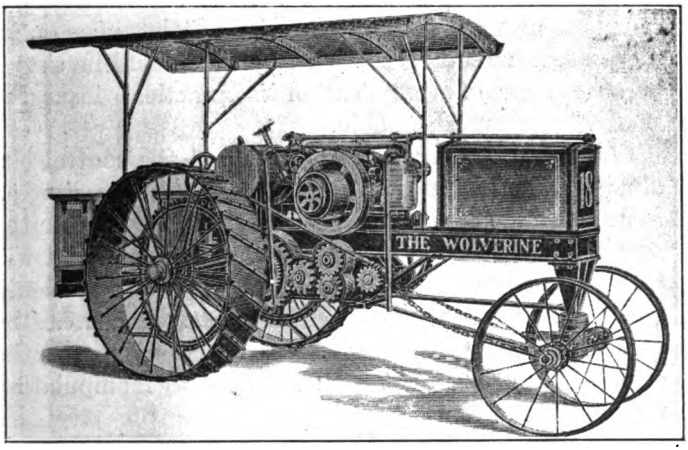

FIG. 8.—The Wolverine Eighteen Horse-power General Purpose Gas Tractor Utilizes Two Cylinder Power Plant.

especially noticeable when climbing grades. If the tractor is too light, it will not have adequate adhesion with the ground and much power will be lost in slipping between the driving wheels and the ground. The weight should be distributed so the greater part of it will come over the rear wheels, as in most constructions these are called upon to do the driving.

Third, there should be a large contact area between the traction members and the ground in order to avoid

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loss of power, packing of soil and slipping. It should be provided with change speed gearing that will provide at least two forward speeds and a reverse motion. The drive from the power plant to the rear wheels should be positive and designed so that there will be minimum loss of energy through friction in gearing.

Fourth, it should be of consistent design for the work it is to do, built of the best materials that can be obtained within reasonable limits and incorporate in the construction strength without excessive weight. The entire mechanism, including the power plant should be simple because lack of complication is practical insurance against mechanical trouble.

Fifth, it should be easy to start and the control elements should be designed so the tractor can be directed without undue expenditure of energy. The simpler the control members, the easier the average farm-hand will find it to handle the machine. The construction should be such that an automatic steering attachment can be used in certain classes of work, such as ploughing, so the engineer may devote part of his time to manipulating the plough shares.

Sixth, it is desirable that the engine be capable of operating on any liquid fuel, especially the cheaper and more plentiful distillates of petroleum.

There are a number of tractors offered at the present day that meet all of the above requirements. The construction is good both from an engineering and practical point of view. The machines are economical to maintain and operate and in many cases, especially in power plant and driving mechanism design, useful lessons have been drawn from current automobile practice. It is safe to say that the tractors which more nearly incorporate the good features and ideal requirements are those which

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follow in a modified form, some of the rules of practice established by automobile designers. In essential elements the automobile and tractor are similar. It is merely in detail arrangement of parts that they vary.

Practical Prime Movers.—Three forms of prime movers are available for mechanical traction. The electric current, which has been used so successfully in moving the heavy street cars and trucks of our cities is not available for farm-traction engines because most of these are operated at a distance from sources of electric current. The steam engine was formerly very popular, in fact, the earliest, really successful traction engines were propelled by steam power. At the present time, however, this prime mover has been succeeded by the more efficient and easily understood internal combustion engine.

Steam and Gas Power Compared.—One of the great disadvantages of steam power is that it requires skilled supervision. In some States, the laws require that the operator of a steam-traction engine shall be a licensed engineer. The supervision of the machine must obtain at all times that it is in service and the engineer is too much occupied in the various duties incidental to keeping up steam and directing the conveyance to give his time to any other work. The average gas tractor does not require skilled supervision. Any person, who can pass the relatively simple examinations required for automobile-driving licenses is permitted to operate a tractor, providing that his physical capacity is equal to the task of starting the engine and handling the tractor under average operating conditions.

Besides this important point, the operating principles of the gas engine are much better understood at the present time because of the wide vogue of gasoline power

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plants for various farm uses and automobiles. In every community of any importance one can find a number of mechanics skilled in the operation and repair of gas engines. This condition did not obtain four or five years ago, as the gas engine was then considerable of a mystery to our agricultural population. At the present time, however, many converts to gas power have been made by the gas-engine manufacturer and thousands of engines have been sold. There are a number of other advantages of gas power that should be considered before the writer explains why the gas engine is the most popular prime mover.

Efficiency of Steam and Gas Power.—The thermal efficiency of the steam engine is considerably lower than that of the gasoline motor. In the former, the heat units contained in the fuel are made to do work by a rather roundabout process of burning the fuel under a boiler to make steam and then utilizing the expansive force of steam in the cylinders of the engine to produce power. There is a big loss in heat units in converting water to steam vapor and there is a further loss of heat when the steam is led from the boiler to the engine. In a gas tractor the fuel is burned directly in the cylinders and less heat units are wasted than in the steam power plants.

The steam engine has one important advantage and that is that it can be operated at an overload for some time. For example, an engine with a nominal rating of 50 horse-power may be made to develop 60 or 70 horse-power by increasing the steam pressure from the boiler. A gas engine does not have the surplus energy to draw from and will not run under the overload conditions a steam tractor will.

The thermal efficiency of the average steam-power

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plant ranges from 18 to 20 per cent, that is to say, only this amount of the heat units contained in the fuel burnt under the boiler is turned into useful work by the steam engine. The thermal efficiency of the gas engine, at the other hand, is often as high as 30 per cent. When compared on a basis of drawbar pull, the relative efficiencies of steam and gas tractors do not vary widely. In tests, as in ploughing, steam tractors have shown an average drawbar pull of 26 per cent. of their total weight and 36 per cent. of the weight on the driving members. Gas tractors as a rule will exert an average drawbar pull of 25 per cent. of their total weight or 35 per cent. of the weight on the drivers.

The average traction rating of gas tractors are about one-half of the brake horse-power rating. In tests with steam tractors over a firm ploughing course they were able to show 56.6 per cent as much power at the drawbar as at the belt in economy tests. Over a hauling course, which presented many different conditions of road surface from the very best to the poorest, the average drawbar horse-power was reduced to 29.3 per cent. of the power given by the engine. In ploughing, some gas tractors have shown a drawbar pull as high as 70 per cent. of the engine power, while in hauling, 50.8 per cent. of the engine power has been exerted at the drawbar.

Why Gas Tractors Are Most Popular.—When one considers the many advantages, ease of operation and economical maintenance of the gas tractor it is not difficult to understand why this form has attained so great popularity. The mechanism is relatively simple and can be started at any time without exasperating delays. Its radius of action is greater than that of a steam tractor because it is more independent as regards a base of supplies. A man can easily carry the amount of water con-

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sumed by the cooling system of the average gas engine in an ordinary pail, while five gallons of fuel will operate it for some time. The steam tractor must have two tenders. These comprise a tank wagon for water and another conveyance for wood or coal. Even if liquid fuel is burned under the boiler, the water tank will be necessary and twice as much liquid fuel will be needed than with a gas engine of the same power.

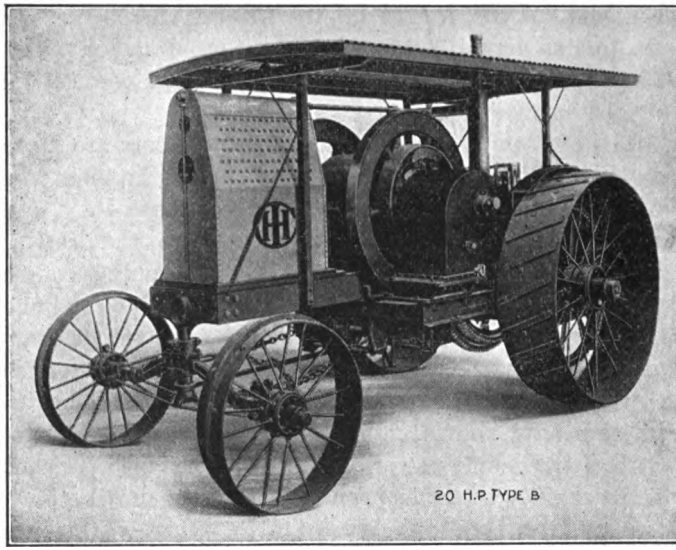

FIG. 9.—The I. H. C. Twenty Horse-power Tractor Utilizes Single Cylinder Engine for Power.

Considerable time is needed to steam up and great care is necessary if the steam tractor is to be operated in cold weather. It is not profitable or desirable to use the anti-freezing solutions in the boiler that can be so conveniently carried in the cooling system of the gas tractor.

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The larger and heavier steam tractors need two men to operate them just as a steam locomotive does. The engineer is occupied in driving and controlling the machine and a fireman is needed to keep fuel under the boiler. The heaviest gas tractor can be controlled by one man.

A steam tractor must be relatively heavier than a gas-operated machine of the same power. While this may be considered an advantage from some points of view, it is a decided disadvantage in others. It is reasonable to assume that it takes more power to move a heavy machine than a light one. The more massive construction will pack the ground more than that having less weight because there is a certain limit to the size of the driving wheels beyond which it is not desirable to go. When a heavy machine becomes mired it is more difficult to pull it out of the hole by other forms of power, or by its own energy.

Gas tractors range in size from 12 to 110-brake horse-power, while steam ploughing tractors are not economical in sizes much less than 25 horse-power. Ordinary steam-traction engines, when ready for work, range in weight from 10 to 25 tons. The gas tractor is also made in many special designs that are not practical with the steam-propelled types, such as orchard tractors and combined self-contained ploughing and traction engines. When one considers the wide range of different gas tractors available, their generally lower cost and lighter weight than the steamers, the fact that a specially licensed engineer is not necessary and their wide adaptability, one can easily understand why they have displaced the steam-propelled machine in practically all lines of work.

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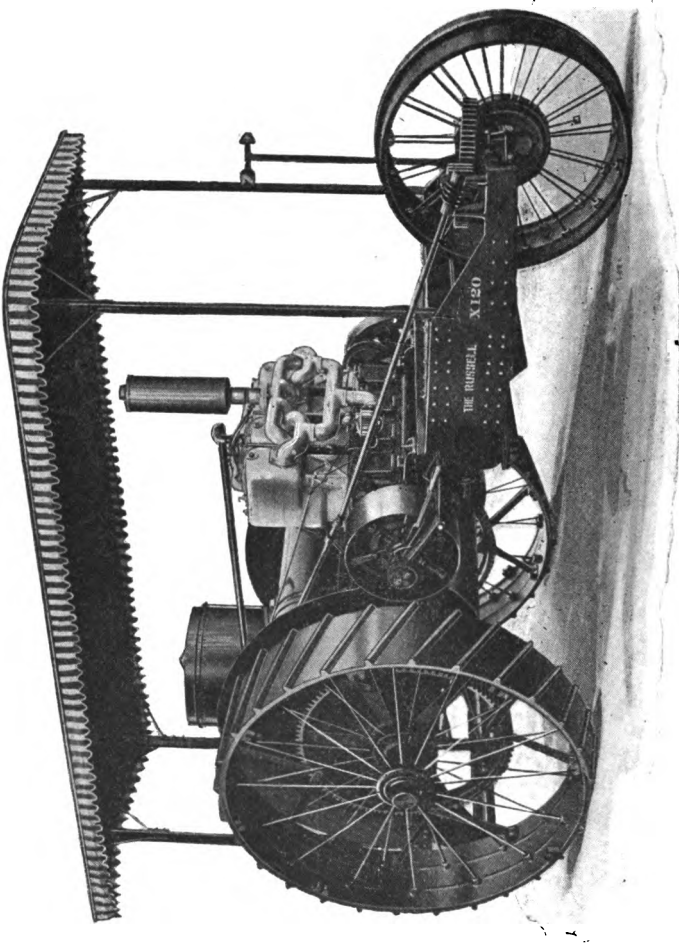

FIG. 10.—The Russell Gas Tractor with Four Cylinder Power Plant, and Single Front Steering Wheel.

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CHAPTER II.

REVIEW OF CONDITIONS ON WHICH TRACTOR DESIGN IS BASED.

Elements of Tractor Design Outlined—Selection of Power Plant—Power Needed for Hauling—Energy Absorbed by Ploughs—Power Delivery Under Belt—Why Proper Distribution of Weight is Essential—Influence of Weight on Traction—Influence of Road or Field Surface on Traction—Effect of Grades on Traction—Types of Tractors—Traction Engines for Small or Medium Sized Farms—Large Capacity Tractors—Parts of Typical Tractors Outlined—Some Distinctive Designs.

Elements of Tractor Design Outlined.—The main part of the gas tractor is the power plant. Next in importance comes the traction mechanism. For the most part the gas engines used in tractor work contain the same essential components as stationary gas engines do. Most of the earlier tractors used the common form of horizontal cylinder stationary engine as a power plant in the one and two-cylinder forms. Many of the present day successful machines utilize engines that are sold by the same manufacturers for stationary work. Some of the latest tractors depart from the old method of construction and the power plants are based more on the lines of automobile motors than of the stationary engines. The supporting frame, driving wheels, differential and power transmission gearing are not radically different from the same parts of a steam tractor.

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The engines of single-cylinder tractors usually run at three hundred to four hundred revolutions per minute. At higher speeds than these, the vibration becomes excessive and all parts of the mechanism are severely stressed. Two and three-cylinder engines, which have a better running balance, are usually run at somewhat higher speeds, and the four-cylinder type, which is practically in perfect balance, both in that of the mechanical parts and torque, due to rapid sequence of explosions, are run at higher speeds. Some of these attain seven and eight hundred revolutions per minute. Gas tractors may be roughly divided into low, medium, and high-speed types, depending on the type of power plant employed.

The group usually considered as the power plant consists of other elements besides the engine. Some form of vaporizer must be provided to change the liquid fuel to a gas that can be exploded in the cylinder. It is imperative that some means of igniting the compressed charge of gas be included. The power plant must be automatically lubricated, this calling for various devices for supplying a regular quantity of lubricant. To keep the engine from overheating some method of cooling the cylinder is always included in the power-plant outfit.

It will be seen that the power-plant group consists of, first, a gasoline or kerosene engine; second, a method of supplying and vaporizing liquid fuel, these members usually forming part of the carburetion system; third, some means of igniting the gas, usually composed of a number of electrical devices to form a complete ignition system; fourth, a water tank or radiator, or an oil-cooling tank, a circulating pump for keeping the liquid in motion around the cylinders and forcing it to the cooler where the heat absorbed is dissipated to the air. These

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various devices form a cooling system. Fifth, the lubrication system which comprises positive mechanical means for supplying lubricant. All of these are of sufficient import to merit a detailed consideration, and will be discussed fully in proper sequence.

The transmission system comprises a clutch, which is used to connect the engine power to the wheels and to release the engine when desired; a change speed and

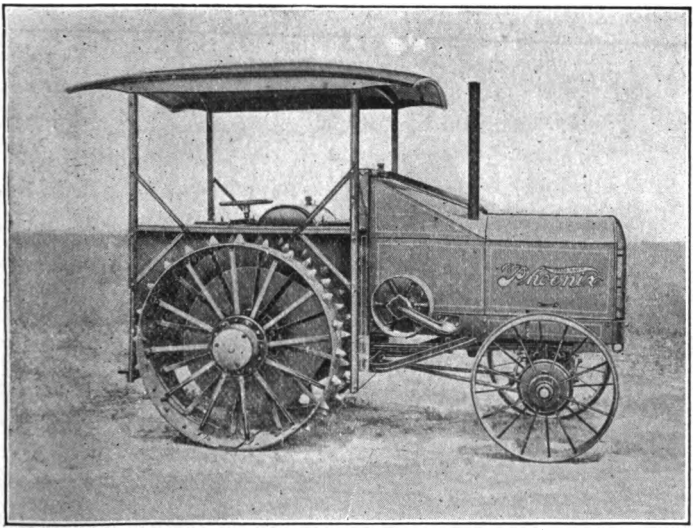

FIG. 10A.—Side View of Phoenix Tractor, A Compact Design.

reversing gearing, which is necessary because the gas engine as ordinarily used is not reversible and not as flexible as the steam engine; and positive power transmission means, usually chains or gears, to transmit the engine power from the change-speed gearing to the traction members.

A frame of substantial construction is needed to sup-

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port the parts and this in turn must be carried on rolling members. Some forms of tractors utilize a three-wheel frame, the single front wheel being used for steering, while others employ four wheels, the two smaller front members being provided with some operating means by which the course of the machine can be changed at the will of the operator.

Selection of Power Plant.—The type and size of engine needed depends on many varying conditions.

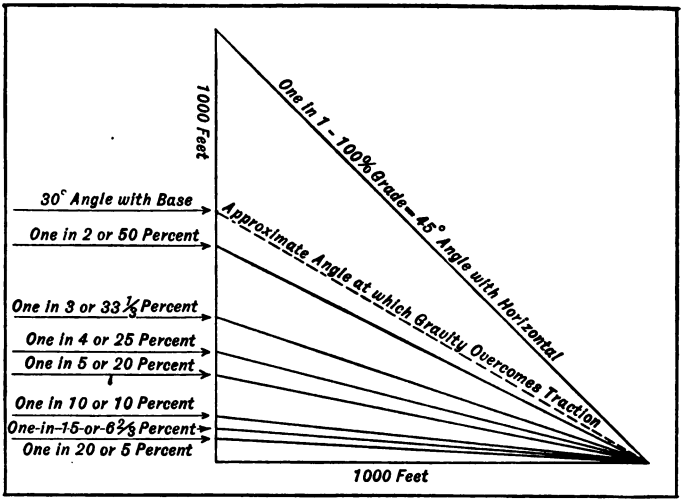
1000 Feet
One in 1 - 100% Grade - 45° Angle with Horizontal
30° Angle with Base
One in 2 or 50 Percent
Approximate Angle at which Gravity Overcomes Traction
One in 3 or 33⅓ Percent
One in 4 or 25 Percent
One in 5 or 20 Percent
One in 10 or 10 Percent
One-in-15-or-6⅔ Percent
One in 20 or 5 Percent
1000 Feet

FIG. 11.—Diagram Showing Method of Calculating Grade Percentage.

The weight of the tractor and its capacity are the first things to be considered. The purpose for which the tractor is intended and the nature of the country in which it is to be operated are also factors of some moment. Another important point is the proposed selling price. One would not expect to find a highly refined and expensively built motor on a light or cheap tractor. Then

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again there would be nothing gained by installing an engine of large capacity in a machine built only for relatively light work. If the tractor is a type that is likely to be used by the farmer of comparatively small means, the engine should be a simple one that will be easily understood and cared for, without too much trouble or expense. Single-cylinder engines are invariably used on low-powered machines. The two and three-cylinder motors are used on machines of moderate capacity, while the four-cylinder power plant is installed in the highest types of construction.

Power Needed for Hauling.—A tractor used for hauling purposes does not need to be as powerful as one used in ploughing or breaking because of the difference in draft required by wheeled vehicles and ploughs. The tractive effort on various surfaces, which means the amount of pull or push necessary to move wheeled vehicles on level roads as given by Norris follows:

On rails or plates	5.16	pounds per ton weight
Asphalt or hardwood	12.24	" " " "
Macadam	30.60	" " " "
Loose gravel	150 to 200	" " " "
Sand	400	" " " "

From the foregoing, it will be seen that the better the surface of the highways over which the load is hauled, the less the amount of power needed to move a definite weight. If it is necessary to haul a wagon train, weighing ten tons over a macadam road, it would require a draft of 306 pounds. To move the same weight through sand will take 4,000 pounds draft. We have seen that a horse-power was equivalent to a draft of approximately 187 pounds at the rate of two miles per hour. In the first case, where the highway surface is good, a drawbar pull equivalent to that exerted by two horses would be

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sufficient to pull ten tons. A 5 to 6 horse-power tractor, if properly designed would be adequate to move this load, provided that there were no grades or stretches of unfavorable highway to be encountered. At the other hand where the road conditions were poor a pull equivalent to that exerted by twenty horses would be needed and a very efficient tractor equipped with a 35 or 40 horse-power motor would be called for.

Other factors besides the condition of road surfaces must be given consideration. The factor of wind resistance, which is so important in figuring power required of motor cars, locomotives or other rapidly moving vehicles can be neglected, but the effect of velocity and gradient must be considered in this connection. The relations of velocity and gradient on traction will be considered fully later.

Energy Absorbed by Ploughs.—If the tractor is to be used for breaking and ploughing it will have to be a powerful one if it is to do an amount of work worth while. Soils differ greatly in their cohesive properties and the amount of draft required to operate a single plough share will vary within wide limits. The average draft of ploughs as determined in an old English test for a furrow 5 inches deep by 9 inches wide made in five different soils was as follows:

Loamy sand	227 pounds
Sandy loam	250 pounds
Moory soil	280 pounds
Strong loam	440 pounds
Blue clay	661 pounds

This represents an extreme range of 194 per cent. One heavy horse would be needed to pull a plough in sandy loam and in doing this he would be exerting a draft, having a value greater than one horse-power. A team of

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two heavy horses would be needed to pull the shares through strong loam, while in ploughing the blue clay, three heavy or four light horses would be required to pull the plough continuously for a working day.

Fifty-seven tests in the varying soils of Missouri gave an average draft of 5.26 pounds per square-inch area of the cross section of the furrow slice turned. Seven trials in clover gave an average of 6.47 pounds per square inch, while six in oat stubble averaged 4.68 pounds. Ploughing in virgin gumbo sod requires a draft of 13.75 to 16.3 pounds per inch. The shape of the plough, the weight, and the adjustment must all be taken into consideration as well as the depth and angle of the cut. The situation may be summed by saying that for ordinary widths and depths of ploughing, the draft per square inch of cross-section ranges from a minimum of three pounds in sandy soil to seven or eight in clay, six or seven in tame clover sod, and ten to fifteen pounds turning the sod of the virgin prairie. The draft of a 6x14-inch furrow would thus present an extreme range of from 250 to 900 pounds, while 400 to 500 pounds is given as an average for old land in the middle West.

From the foregoing it will be evident that in ploughing the full capacity of a tractor must be used. A 30 horse-power tractor, which delivered 50 per cent. of its brake horse-power or 15 horse-power at the drawbar would exert a pull equivalent to 2,810 pounds at the rate of two miles per hour. In soil requiring a draft of 200 pounds per plough it could pull a fourteen-bottom gang, while in exceptionally heavy soil, requiring a draft of 500 pounds per ploughshare its capacity would be but a six-bottom gang. It will be seen that the lighter tractors having comparatively low-powered engines cannot be used as economically as the larger ones for extensive

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ploughing, though they are practical for hauling purposes, or for ploughing on small farms.

Power Delivery Under Belt.—Most traction engines are provided with a pulley by which the motor may be coupled to any form of machinery that can be driven by a belt. In this work practically the entire brake horse-power of the motor is available, as there is but little loss in transmission. When it is used for traction purposes part of the power is being used in moving the machine over the ground and part is being lost in friction in change speed and driving gearing. An engine that may deliver 30 horse-power under belt would not deliver more than 15 horse-power at the drawbar under ordinary conditions.

Why Proper Distribution of Weight is Essential.—To get the largest proportion of power at the drawbar the gas tractor designer is forced to consider a number of important conditions. First, the engine must be strong and durable and the friction losses through gears and shafting must be reduced to a minimum. Second, the design of the machine and the distribution of weight must allow the engine to travel over a great variety of soils.

The weight must be so distributed and carried that it will consume the least possible amount of power to drive the engine. The successful traction engine must be capable of running over wet, and sometimes muddy ground, over soft-ploughed ground, or over rough field surfaces. Every horse-power that is used to move the engine is lost and only that available at the drawbar can be counted in traction work. The engine designer should consider concentrating the weight of the engine where it can be carried to best advantage. If the bulk of the weight is placed at the center of the frame so the load is

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carried on both front and rear axles, the amount of power delivered at the drawbar is greatly reduced unless the machine is a four-wheel drive or other special design.

The front wheels should not carry any more load than will hold them in contact with the ground with sufficient pressure to insure positive steering. The smaller the front wheels are in diameter and the more weight carried by them the greater the amount of power it requires to force them ahead and the more difficult it is to control the tractor.

In order to secure the greatest tractive efficiency the greater part of the weight should be carried over the rear axle. The engine should be placed at such a point that the front end will not be overloaded or the frame stressed unduly. When the motor is placed parallel with the frame and when the bulk of the gearing is carried by the rear axle the greater portion of the strain due to weight and vibration will pass directly to the ground. The degree of adhesion between the rear-driving members and the road or field surface depends upon the amount of weight that keeps them in contact with the ground. It should not be inferred that tractors having the engine placed in front or in the middle of the frame are not practical, as many of these have given exceptionally good results in practice.

Influence of Weight on Traction.—When a motor-propelled vehicle travels on a level course its tendency to forward motion is resisted by three main items. The most important of these is the rolling resistance at the point of contact of the wheels with the ground. Of the other two, the friction in the rear axle and driving mechanism and the air resistance; the influence of the latter may be neglected in such slow-moving vehicles as tractors. If the vehicle is travelling up a grade the power

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required to lift the weight up the incline should also be considered. The road resistance, as we have seen, depends to some extent on the character of the road surface, but another factor is the diameter of the wheels and the speed at which the vehicle travels. In the table previously given, we have seen that on a good macadam road a pull of 30.6 pounds would move a ton, therefore the heavier the tractor the greater the amount of power needed to overcome the resistance of the road. The horizontal effort required to pull a tractor up a grade is equal to about 1 per cent. of its weight for each per cent. of the grade. If we have a tractor weighing 10,000 pounds and we wish to pull it up a 10 per cent. grade it will require a pull equal to 10 per cent. of the weight or 1,000 pounds. This added to the traction resistance of 30.6 pounds per ton means that an added pull of 153 pounds must be considered in connection with the amount of force needed to climb the grade. Obviously a lighter tractor would not require so much power on grades and could be operated by an engine of less power. At the same time as the amount of adhesion between the wheels and the ground would be less in case of the light machine, its traction capacity would be reduced in direct proportion.

It will be apparent that there are extremes which the careful designer will avoid. A heavy machine with an inadequate power plant or with an inefficient system of transmission will not be practical because it could not surmount grades and would not have the range of work that its size would indicate. At the other hand the mistake can be made of using too large a power plant in a light machine. This would mean that while it would prove to be a good hill climber or have a capacity for hauling, it would not have weight enough to insure the

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delivery of its full drawbar horse-power on account of the limits in traction imposed by the light weight on the rear wheels. This is overcome in some constructions, notably in the combined self-contained ploughing and traction machines where the ploughs are carried under the frame of the tractor in such a way that the resistance offered by the earth to the cutting action of the plough will hold the wheels firmly against the ground and thus increase the available tractive effect. In this way a light machine that would not be adequate to pull a trailer plough will handle the ploughs provided as a part of its structure with ease.

Influence of Road or Field Surface on Traction.—We have seen by the table, previously considered that the draft required to haul wagons varied according to the nature of the road surface. The harder the surface over which the wheels rolled, the less the amount of pull needed to keep the vehicle in motion. The following

Grade.		Macadam Road.		Firm Earth Road Not Sticky.		Soft Muddy Road.		Soft Field.	
Ft. per mile.	Per cent.	Draft	H.P.	Draft	H.P.	Draft	H.P.	Draft	H.P.
Level	0	2,135	10.82	2,500	12.67	2,650	13.43	3,040	15.40
53	1	2,405	12.19	2,770	14.04	2,920	14.80	3,310	16.77
106	2	2,675	13.55	3,040	15.40	3,190	16.16	3,580	18.14
158	3	2,945	14.92	3,310	16.77	3,460	17.53	3,850	19.51
211	4	3,215	16.29	3,580	18.14	3,730	18.90	4,120	20.88
264	5	3,485	17.66	3,850	19.51	4,000	20.27	4,390	22.44
422	8	4,295	21.76	4,660	23.61	2,810	24.37	5,200	26.35
528	10	4,835	24.50	5,200	26.35	5,350	27.11	5,740	29.08
634	12	5,375	27.24	5,740	29.08	5,890	29.84	6,284	31.82
792	15	6,185	31.34	6,550	33.19	6,700	33.95	7,090	35.93

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table gives the horse-power and draft required to pull a 13½-tons tractor over various grades and road surfaces at a net speed of 1.9 miles per hour and shows clearly the effect of varying road and field surfaces on traction.

Brief study of the table will show that the variation in draft for different road surfaces is not as great as for wagons. The amount of pull needed ranges from 160 to 225 pounds per gross ton. These figures are higher than are usual with wagons and may be ascribed to the greater internal friction existing between the various parts of the mechanism. In a test a ton of engine weight required a draft 20 per cent. greater than the same weight of wagon and load. If a constant figure or allowance for the friction of gearing could be made and substracted from the draft per gross ton in each case the difference in draft due to road surface would be more strongly emphasized. As it is, it required from 40 per cent. to 50 per cent. more power to pull the tractor over soft-field surface than it did over macadam road.

Effect of Grades on Traction.—On grades the internal friction and ground resistance are constant factors, providing that the road surface on the gradient is the same as obtains on the level highway. In the above table the variation between the power needed to move a tractor on the level and on grade is due to the effort expended in lifting the tractor. Under actual service conditions, the internal friction to be allowed for would depend entirely upon the design of the transmission mechanism and the care taken to keep the various bearings, gears, etc., well lubricated and in line.

An authority has stated that allowing 250 pounds of resistance per ton of weight would not be too much in estimating the power required to move the average tractor over an ordinary road. Each per cent. of grade

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adds 1 per cent. of the tractor weight to the resistance or 20 pounds per ton. For example, it is desired to estimate power required to move a 12-ton tractor up a 10 per cent. grade at 2.5 miles per hour. The following equations show the method of determining this:

$$(12\times250)+(12\times10\times20)=5{,}400 \text{ pounds.}$$

$$\frac{5{,}400\times2.5}{375}=\frac{13{,}500}{375}=36 \text{ horse-power.}$$

Considerable difference of opinion obtains as to the methods of calculating grade percentages and some confusion may exist in the mind of a non-technical reader regarding the difference between the percentage and angle of a grade. A diagram is given at Fig. 11, which shows the method in vogue graphically. If it is assumed that the base of the triangle represents a line 1,000 feet long and that the first sloping line represents a road having a rise that brings it 50 feet above the starting point this would be considered as a rise of 50 feet in 1,000 feet or one in twenty and would correspond to a 5 per cent grade. The rise is based on the length of the base line not of the hypothenuse of the triangle, which is represented by the inclined roadway. A grade which represents 100 per cent. corresponds to an angle of but 45 degrees and not 90 degrees, or perpendicular, as is commonly supposed. When the grade becomes steep enough so the angle of inclination is over 30 degrees, gravity overcomes traction and some positive method of drive such as gear wheels running on toothed tracks are necessary to climb greater gradients than 30 degrees angle.

The following table gives the percentages and corresponding angles of inclination for gradients ordinarily met with, except in the very mountainous sections of the country:

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TABLE OF GRADIENTS.

Grade.		Equal to Angle of	Rise or Fall in One Mile, Feet.
Per Cent.	Units.		
20	1 in 5	11° 19′	1,056
17	1 in 6	9° 26′	880
14	1 in 7	8° 09′	754
12.5	1 in 8	7° 08′	635
11	1 in 9	6° 17′	586
10	1 in 10	5° 43′	528
9	1 in 11	5° 11′	480
8	1 in 12	4° 46′	440
7.75	1 in 13	4° 24′	406
7	1 in 14	4° 05′	337
6.5	1 in 15	3° 49′	352
6.25	1 in 16	3° 35′	330
6	1 in 17	3° 22′	310
5.5	1 in 18	3° 11′	293
5	1 in 20	2° 52′	204

Types of Tractors.—The various constructions that can be termed "gas tractors" vary from the small self-propelling lawn mowers to the heaviest machines equipped with engines of over 100 horse-power. Of the many types of tractors offered the public the most common and that which enjoys the widest sale is the medium capacity outfit that will handle about six ploughs as well as any of the other farm machines generally used on medium sized farms. The field for the very light tractor is not a large one inasmuch as these are suitable only for hauling and for work under the belt. Their capacity is not large enough to make them profitable in anything except the lightest forms of work. While traction engines are on the market with power plants as low as 10 horse-power they are not as practical for

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general service as those which have twice the power and cost but little more. In some special classes of work the light tractor has a field but in general the practical type is seldom equipped with less than a 20 horse-power engine.

Tractors have been designed for use in orchards that are moderately light, if compared to the large machines used on the prairie farms of the Middle West. They are entirely suited for the work they are to do and give good results in practical use. A man owning a small farm, such as one that would find work for about four horses can use the lighter tractor to advantage,inasmuch as it will do all the ploughing that the horses will and when not employed in the field the engine can be utilized in all of the various duties which require stationary power where horseflesh could not be used. Tractors having 30 horse-power engines are quite common and are generally used in road work as well as on medium sized farms.

Tractors vary in type at present just as widely as did automobiles of a decade ago. Owing to the infancy of the gas tractor industry there has been no attempt at standardization as is now the case in automobile construction. Some tractors on the market are very rough in construction, and appear to have been evolved by a cut-and-try method, rather than attempting to follow any definite plan or design. Others show evidence of careful thought and study of engineering principles. In some of the cheaper machines cast iron is widely used as a material of construction. Power is transmitted through inefficient cast gears which are exposed to the dirt and grit of the field and which can never be adequately lubricated. The power plants are heavy stationary engines and the entire mechanism is inefficient and crude. The

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machines that are carefully designed use steel forgings instead of castings, utilize power plants of the automobile type, employ the best cut steel gearing, thoroughly encased, to protect it from the dirt and well lubricated to insure long life and efficient operation. The mechanism is thoroughly protected from the elements and the control members are conveniently placed so that they may be easily handled by the operator.

As can be expected, the machines using the best construction and materials and based on correct engineering principles are more costly than the hastily designed and crudely constructed machines. This is a case where first cost is of less importance than after cost or maintenance expense. The well-designed machine will be serviceable under conditions that will quickly consign the cheap mechanism to the scrap heap. The farmer who intends to purchase a tractor should look into the construction and engineering features of the various types very carefully before purchasing. Many who condemn gas tractors as impractical pieces of machinery do so because they purchase poorly designed machines, either through ignorance of mechanical principles or because the low selling price proved attractive. A farmer would not expect the amount of work out of a cheap horse, or in fact, any farm machine that he would get out of the more expensive one. As a rule one gets no more than one pays for and this applies just as well to the purchase of a gas tractor as to a mowing machine, cultivator, or any other farm implement.

Traction Engines for Small and Medium Sized Farms.—Many farmers are of the opinion that traction engines are only suitable for large farms where extensive areas must be cultivated. This is a misconception that is not borne out by the actual facts. Even if the area

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under cultivation is not a large one power traction would permit of more thorough soil tilling than is possible with horses. On every farm forage plants must be chopped, corn shredded and shelled, wood sawing must be done during the winter months, and water must be supplied in abundance at all times in the year. Engine power is the only practical energy for this work.

In many districts, a great advanatge can be gained from deep ploughing, which is necessary to liberate the fertility of new soil. Deep ploughing is not possible with horse-power because the average farmer who has humane instincts hesitates to plough as deep as may be desirable through fear of cruelly abusing his animals. It will be seen that even the small or medium sized farm can use a tractor to advantage in ploughing work, providing that it can be adapted to other labors at periods when ploughing is over. Disking and thorough harrowing are necessary to prepare a good seed bed and proper pulverization of the soil is necessary to retain moisture. The advantage of an engine on a small farm is that it can do this work as well as ploughing and in many cases the same power plant to which ploughs are attached will do the disking and harrowing at the same time.

Many of the smaller farmers are just beginning to recognize that animal power is slow and that the increased number of horses made necessary by the modern methods of farming are not only expensive in first cost but necessitate setting aside some of the most valuable land for raising hay and grain to feed the animals. A number of tractor manufacturers are furnishing medium weight machines equipped with 30 horse-power engines that will do the work of fifteen horses at the drawbar. These have been designed especially to meet the general demands of the smaller corn belt farms of the Middle

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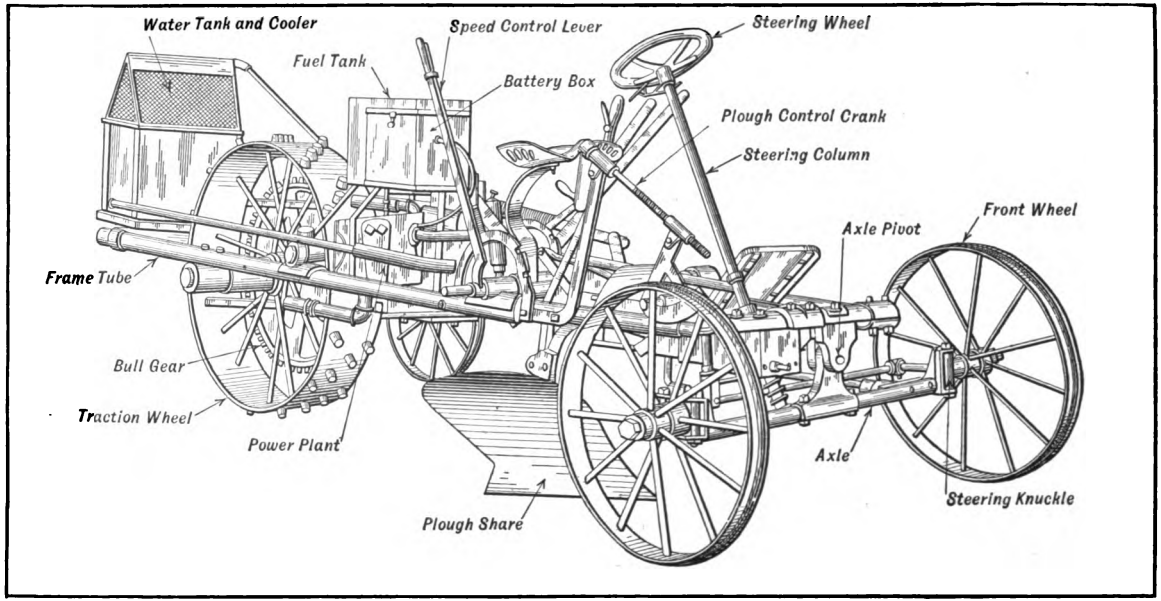

FIG. 12.—The Denning Motor Machine Carries a 16" Plough Under Driver's Seat and is Well Adapted to General Farm Work.

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West. Such a machine will pull a four bottom gang in breaking and six in ploughing. From ten to fourteen acres a day can be ploughed and harrowed in one operation. These machines are easily handled as they will turn short and work closely into the corners of the field. It is claimed that two good sized boys with a machine of this character will easily do the same amount of work that twelve horses and four men will do in a day. Such a tractor will run up to a 32-inch separator and will operate corn huskers, shellers, shredders or any similar machinery. Any farmer working 160 acres can use such an outfit with profit.

Even the small farmer can use one of the combined self-contained ploughing machines to advantage as there are some on the market that cost less than four horses and that will accomplish more work of an all-around nature than the animals will. Such a machine is shown at Fig. 12 and has the plough hung under the operator's seat and about midway of the frame. With a 16-inch plough a man can do as much work as he would with four horses, as the machine will travel on the low gear as fast as a good team will ordinarily walk and will be much faster on the high gear. The low ratio of speed is used for ploughing and other heavy work, requiring considerable draft, and the high gear is employed for cultivating, hauling a light load, or travelling on the road.

For ploughing the share is set inside of the frame with the front end of the beam attached to a malleable casting under the front end of the frame. The driver sits directly over the plough, which is in full view at all times. The right-hand steering wheel runs in the furrow ahead of the plough and the traction wheel in the next furrow behind the plough, thus putting two wheels

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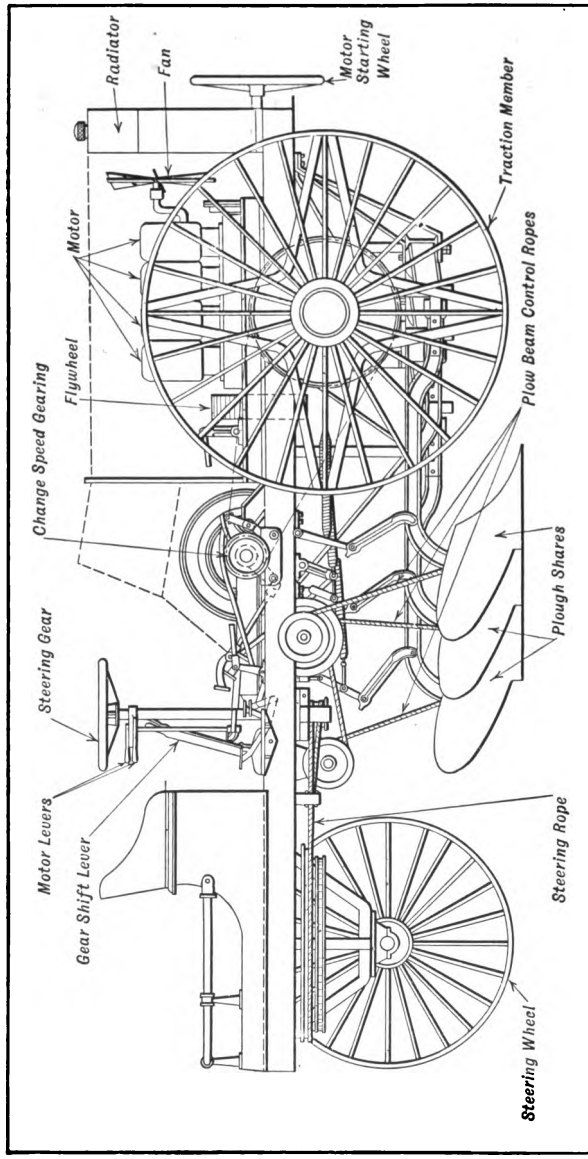

FIG. 13.—The Hackney Auto Plough Carries Three Ploughshares Under Frame and Uses Front Wheels for Traction.

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carrying seven-eights of the load in the bottom of the furrows where the ground is solid. The makers claim that it takes less power to push the machine under these conditions than if running in loose soft stubble ground or over rough prairie sod. This motor machine will pull a seeder or drill in conjunction with a two-section harrow, thus doing the work of two men and two teams on the small farm. It will pull a six or seven-foot d sk harrow, which requires three or four horses and do it at less expense. In addition to the work in the field it will run a medium sized ensilage cutter for filling a silo and will furnish power for all the other farm tasks that can be performed by an engine.

This machine is recommended for orchard cultivation because it is low enough to permit it to get around under the low branches of the trees. Many orchardists do not care to handle horses around their trees because they are awkard and need constant watching to prevent them from nibbling at the young shoots and nipping off the tops of small trees. A machine of this size also has the advantage that it may be easily stored in any shed or barn that will house the ordinary horse-drawn vehicle. Many of the odd jobs that need to be done, such as hauling a load of manure or hay can be accomplished with this machine.

The convenience and ease in handling makes a tractor of this size practical for many things that the larger ones could not be used for. It is as easy to control as a horse and as it will back up as well as go forward it can be moved around in nooks and corners where a horse and wagon outfit could be handled only with difficulty. Another form of self-contained ploughing machine with the parts clearly indicated is shown at Fig. 13. This has larger capacity and is a more powerful mechanism than that

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previously described. Three ploughs are provided under the frame, these being controlled by the operator sitting above them. They may be removed and a road scraper attached under the machine as at Fig. 14, or this attachment can be dispensed with and the machine used for general hauling and power purposes.

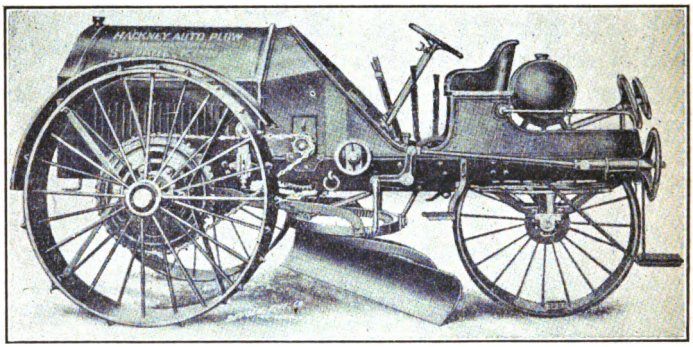

FIG. 14.—The Hackney Auto Plough With Road Scraper Attachment, a Practical Machine for Highway Work.

Large Capacity Tractors.—The first class of gas tractors, in which those having power plants ranging from 18 to 30 horse-power are included, are capable of handling three or four ploughs in ordinary sod breaking and are used on medium sized farms. The second class is provided with engines of 40 to 50 horse-power and will handle up to seven ploughs in heavy work. This and the largest class, which ranges from 60 to 75 horse-power with the ability to pull from eight to ten ploughs under the same conditions are used on the larger farms. Some large machines have been made, which will pull twelve ploughs, but these have not been sold as extensively as the medium weight outfits because they are so large and powerful that they cannot be used on anything but

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large farms to advantage. These machines require two men to handle them, one to run the engine and the other to handle the load of ploughs. While costly to purchase and operate, they have such a large capacity that they are economical if operated at capacity.

The very large machines have some disadvantages. Owing to their weight they tend to pack the ground and it is only in ploughing that their full capacity can be used to advantage. Many operators of large farms prefer to divide the initial investment required for one of these massive machines and purchase a number of the medium sized tractors, even though it takes more help to operate them, and do the same amount of work that the large machine will perform. It is safer to have the work divided among a number of machines rather than employing an extremely large one, because failure of one of several tractors will not prove so serious as when the one large machine refuses to operate. Except in unusual cases, even the operators of very large farms prefer the medium class tractor to the heavy types.

Parts of Typical Tractors Outlined.—The plan view presented at Fig. 15 shows clearly the various parts of a typical gas tractor and their relation to each other. The machinery is carried on a frame made of structural steel supported at the front end by an axle of the pivoted type, having steering knuckles to which the front wheels are attached. In this construction the axle does not move, but the wheels can assume the angle required for describing a curve, because the tiebar which joins the steering arm actuates both wheels in unison. The front wheels of a tractor of conventional design are always smaller than the rear members because they are generally used only for steering, and do not carry a large proportion of the tractor weight in most constructions.

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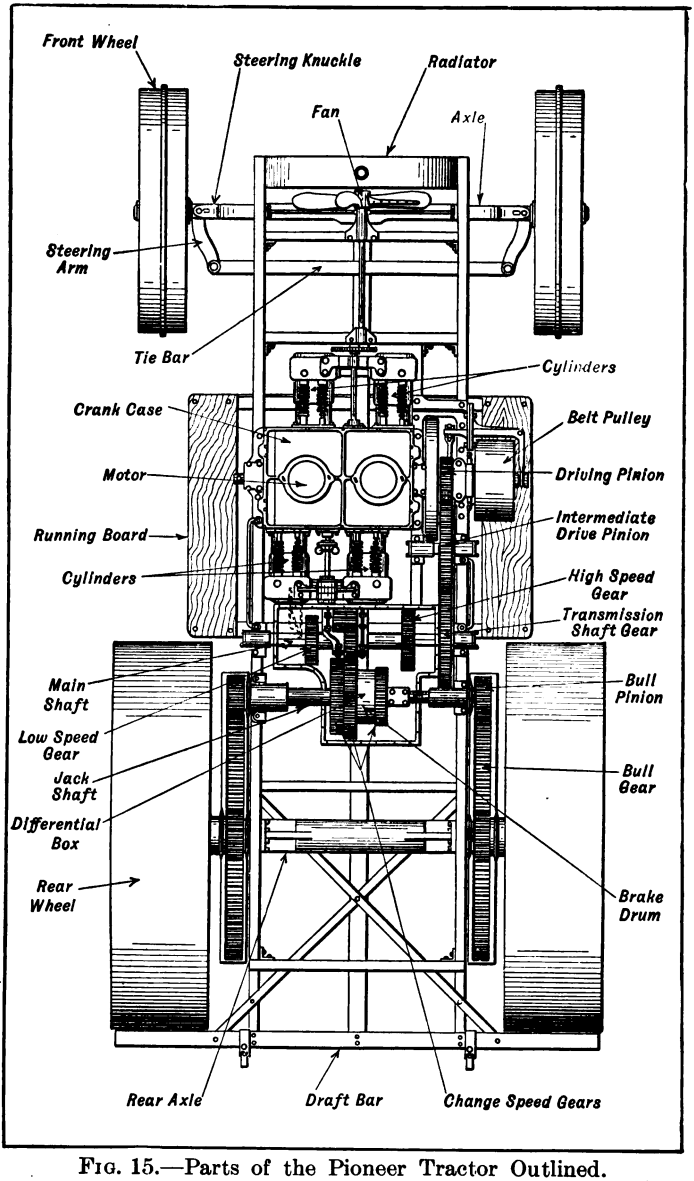

FIG. 15.—Parts of the Pioneer Tractor Outlined.

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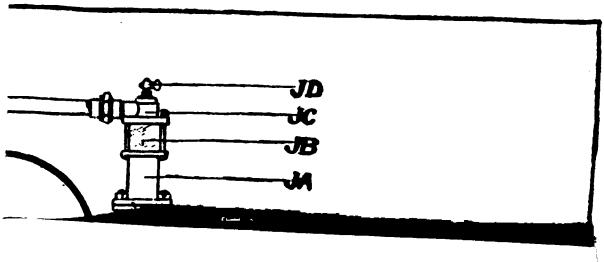

5.—Parts of the Pioneer Tractor Outlined.

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Mounted at the front end of the frame are cooling fan and radiator. The latter is used to carry a supply of water for cooling the engine cylinders and also to cool the heated water from the engine that is pumped through it. This member forms a very important part of the cooling system. The air fan placed back of the radiator is positively driven by gearing from the engine and serves to draw a blast of air through the openings of the cooler, and abstract the heat from the walls of the tubes through which the water circulates.

The power plant in this case is carried about midway of the frame and is composed of a four-cylinder gasoline engine, having opposed cylinders horizontally disposed, the crankshaft of the motor being at right angles to the frame. Beside the motor fly-wheel a driving pinion is mounted, this communicating with the main shaft of the transmission by an intermediate drive pinion, which meshes with the driving pinion on the engine crankshaft and with a large gear on the transmission mainshaft. A belt-pulley is mounted outside of the frame on the crankshaft extension, this enabling one to obtain power from the engine for running various machines. A clutch is provided on the engine shaft, so the driving pinion may be put in action or so the belt pulley may be clutched to the shaft.

When the driving pinion is turning with the shaft it produces motion of the transmission mainshaft which is a square member, carrying three sliding gears actuated by a common shifter member. When the smaller of these gears is meshed with the medium sized gear attached to the differential gear case a slow speed ahead is obtained. When the gears are in the position shown a reverse motion is obtained. The gear on the main shaft is driving an intermediate pinion at the bottom of

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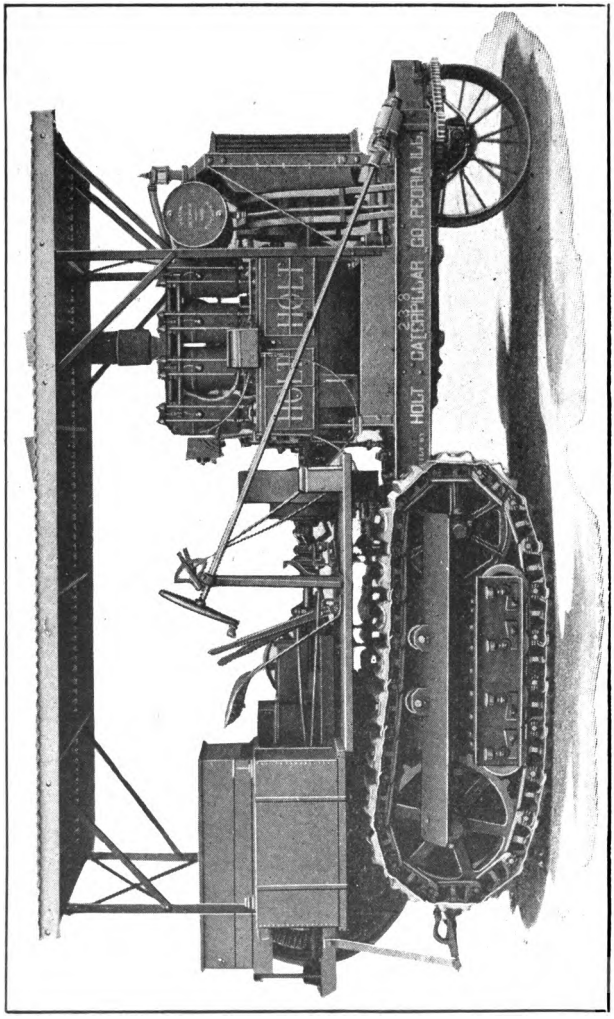

FIG. 17.—Holt Caterpillar Tread Tractor. A Distinctive Design Suitable for Soft Soils or Any Other Condition Where Wheel Tractors Would Work at a Disadvantage.

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the gear case which in turn operates the largest gear on the differential casing. When the largest gear on the main shaft is engaged with the smallest gear on the differential box the high speed forward is obtained.

The differential mechanism, the action of which will be described more in detail later, is necessary with all forms of self-propelling vehicles where two wheels are driven from a common source. Without it the automobile or traction engine would not be practical. It permits the outer wheel to revolve faster than the inner wheel when the machine is turning a corner. Leading from the differential gear are two shafts which carry bull pinions at their outer ends. These engage with the bull gears which drive the large rear wheels of the tractor. The rear axle is a substantial fixed member on which the rear wheels revolve.

The cut previously described shows clearly the relation of the power plant to the driving wheels and outlines the various gears through which the engine power is transmitted and by which the engine speed of four or five hundred revolutions per minute is reduced to a few revolutions per minute of the driving wheels. The side elevation outlined on the large folding plate, Fig. 16, outlines clearly all the parts of a large capacity tractor of the Caterpillar tread type. As the key clearly defines the various parts their functions will be readily apparent.

Some Distinctive Designs.—Special designs of tractors have been devised to do work more efficiently than the conventional forms. For example, for overcoming the disadvantage of very soft ground no device appears to be more successful than the substitution of a Caterpillar tread for the ordinary type of traction wheel. A tractor of this form is shown at Fig. 17 and has proved very satisfactory in practice. It has been used on

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swampy ground where wheel tractors could not turn a wheel and it has found a field of usefulness in hauling lumber on the soft snow-covered roads of the great Canadian forests. This idea is several generations old but it is only recently that tractors having this type of transmission have been put on the market in large numbers.

The weight of the tractor is supported on steel rollers, which run on the inside of a continuous belt made of steel plates, joined together so they can run around wheels at the front and rear of the truck. This means that the tractor lays a track and picks it up as fast as it is no long needed. The front of the tractor is supported by a single wheel, so under actual working conditions nearly all the weight of the tractor is carried on the rear where it is distributed over such an area of ground contact that the weight carried is but five or six pounds per square inch as compared to the forty to ninety pounds ordinarily supported by each square inch of wheel surface in contact with the ground on the conventional type of tractor. This Caterpillar tread and driving mechanism are described in detail in the chapter dealing with the tractor frame, wheels and axles.

Some experiments have been made abroad with power-propelled machines carrying a large drum at the rear driven by chain connection from the rear wheels. These drums carry a number of teeth or small spades, which dig into the ground and break up the surface in the same way that a multitude of picks would do. Other forms have rotary ploughs carried at the rear end.

A tractor that has been well received by many farmers is built on the order of the motor truck used in cities for hauling merchandise. It will carry a load of three tons in the wagon bed with which it is provided

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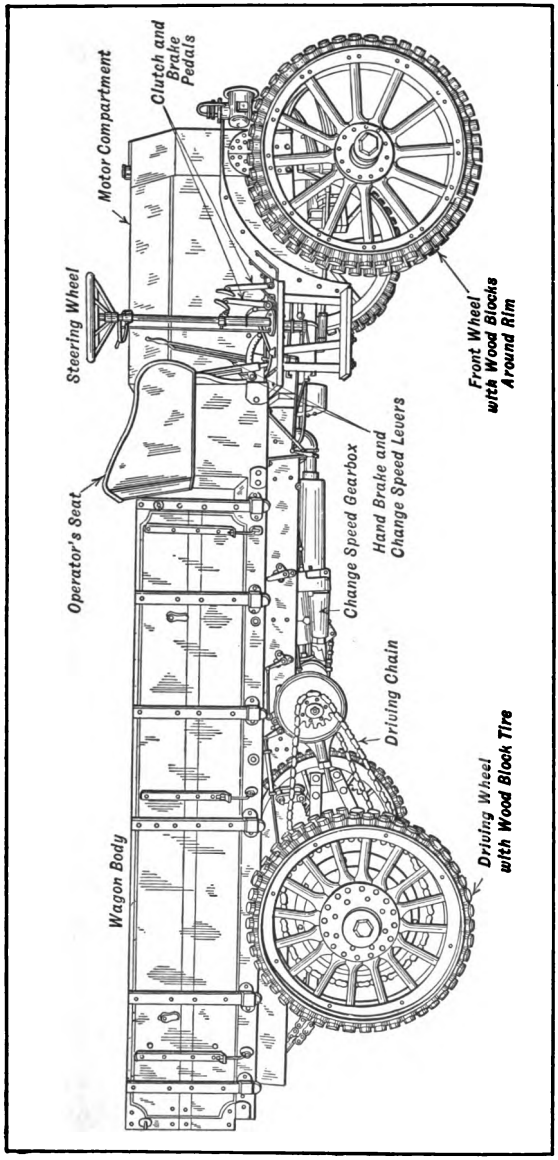

FIG. 18.—The Avery Farm Truck, a General Purpose Machine Powerful Enough for Traction Work in Field, Capable of Hauling on Roads and Its Engine is Suitable for Stationary Power if Desired.

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and has a pulley for driving stationary machines. A drawbar is provided for pulling ploughs and other machines requiring draft. The weight of this truck is carried on four wheels, therefore when used for ploughing ballast must be put over the driving wheels in order to provide proper traction. As the machine is spring mounted and adapted to speeds from two to fifteen miles

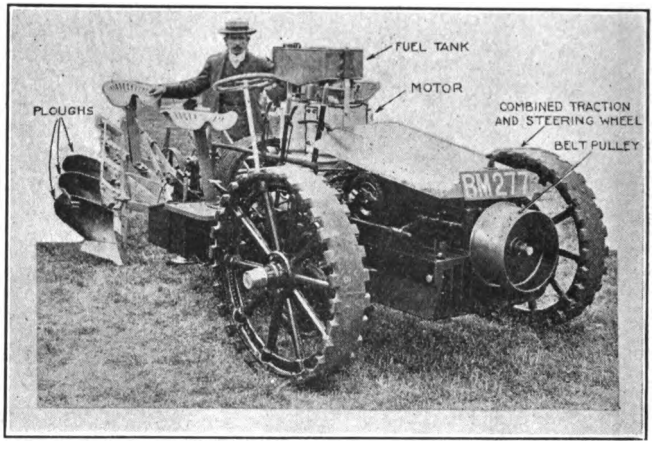

FIG. 19.—An English Tractor With Three Bottom Gang Plough. This Machine Driven by Two Cylinder Vertical Motor Utilizes Front Wheels for Steering and Traction Duty as Well.

per hour it can be used for a wide variety of work. Instead of using rubber tires as the ordinary motor truck does, the wheels are provided with wooden plugs to adapt the tractor to hard roads. Traction on soft ground is provided by an extension rim with a number of mud lugs attached, which is so fastened to the wheel that these automatically grip the soil when the wheels sink to a certain depth. It is also possible to move a hand

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lever on each driving wheel which causes a series of sharp spikes to project beyond the periphery of the wheel to increase traction when desired.

A machine of this nature is shown at Fig. 18 which clearly outlines the general construction. As will be seen in general form it does not differ radically from the usual type of motor truck. As it is provided with a wagon bed it will haul grain, hay, stock, coal, lumber, milk, fruit, vegetables and other kind of merchandise. It has sufficient tractive power to pull three 14-inch ploughs and a harrow in ordinary stubble ploughing and will plough an acre an hour. It will pull two disks, two spike harrows, two seeders, two binders, corn planters, a road grader, a train of loaded wagons, or any other machinery. It has a draft equal to ten horses. This general purpose machine, therefore, is ideal for the small or medium sized farm as it will not only haul loads of all kinds on its own body but will do field work and serve as a portable belt-power plant when desired.

Many other special tractor forms have been evolved, ranging from crudely fashioned home-made contrivances to highly specialized types adapted to do only certain kinds of work. Obviously the general purpose tractor must suffer if compared to one designed to do a specific kind of work, but its wide adaptability gives it an advantage over the specialized forms that more than compensates for its lack of capacity in any specific work.

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CHAPTER III.

DESIGN AND CONSTRUCTION OF GAS TRACTOR POWER PLANTS.

Power Rating Basis—Indicated, Brake and Drawbar Horse-power—Types of Gas Engines—Comparing Two and Four Stroke Cycle Power Plants—Operating Principles of Four-Cycle Engine—How Two-Cycle Engine Works—Advantages of One Cylinder Motors—Features of Multiple Cylinder Motors—Heavy Duty and Medium Duty Engines—One Cylinder Tractor Engines—Two Cylinder Engines—Three Cylinder Power Plants—Tractor Motors with Four Cylinders.

Power Rating Basis.—In referring to the power of the various internal combustion engines used as prime movers, a number of terms are employed in dealing with the subject that may prove confusing to the layman. Therefore, before going into the theory of engine operation to any extent it will be well to define the various methods of rating. Many believe that there is a difference between a gasoline or electrical horse-power, that produced by a steam engine or from the animal itself. The unit of work remains the same regardless of the source of energy and whether the power is produced by steam, gas, electricity, wind, water or horses. Various equivalents for a horse-power are used, for example an electrical horse-power is 746 watts. There are actually four common methods of horse-power rating in use, each of which carries an intelligent idea of its meaning.

Indicated, Brake and Drawbar Horse-power.—Indicated horse-power is the amount of energy developed within the cylinders of any heat engine. It is

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determined by an instrument called the indicator, which gives a card or graphic chart showing the pressure in pounds per square inch exerted upon the piston of the engine. This is most commonly used in steam-engine practice and is a unit of interest mainly to the engineer or designer because it does not give the actual power developed by the motor. There are mechanical losses that must be considered before the actual power output of the power plant can be ascertained.

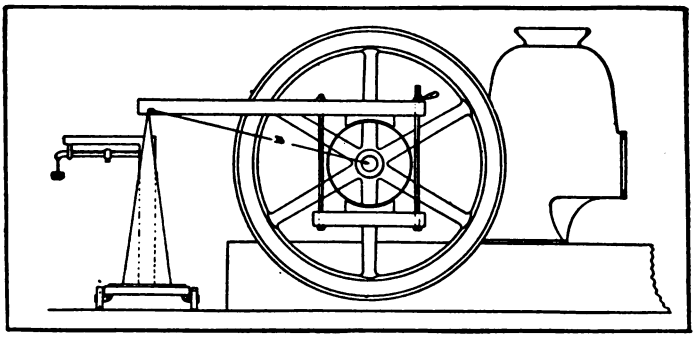

FIG. 20.—Simple Diagram to Show One Method of Making a Brake Test of Small Engine.

Brake horse-power represents the indicated horse-power, less the losses in friction of the working parts of the motor itself. It is the power actually delivered to the crankshaft or belt pulleys of the motor. The brake horse-power is easily determined by any form of absorption dynamometer of which the Prony brake is the simplest form. The application and use of this form of power indicator can be clearly understood by referring to Fig. 20 and from table given in Appendix. Any one can make the simple testing device illustrated, without any other instructions than given in the cuts. Good stout 4×4-inch lumber, free from knots; two

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blocks curved to conform to the periphery of the belt pulley; two bolts as indicated and an ordinary platform scale are all that is needed. The length of the horizontal brake beam represented by the letter **B** is not arbitrary, it being necessary only to make sure that this should be short enough and have sufficient strength to prevent breaking when under test.

When making a test, the first thing to do is to have the engine running at its normal speed and under proper conditions to get steady power. The brake blocks do not bear against the belt pulley with any force except that produced by their weight. The nut on one of the bolts is then tightened to bring the brake blocks in forcible contact with the pulley. This tends to depress the end of the brake beam resting on the load transfer member, which is supported by the platform of the weighing apparatus. The brake beam should always point in the direction toward which the fly-wheel is turning.

The rule for obtaining the power delivered by the motor is a simple one. Multiply the speed at which the engine pulley is turning by the number of feet in the circumference of a circle having a diameter twice that represented by the radius **B** and then multiply this result by the net pounds lifted on the scale when the two nuts on the top end of the bolts have been screwed down sufficiently so that the brake blocks are bearing on the engine pulley as hard as possible without reducing the motor speed. Divide this result by 33,000 and the quotient will equal the actual power of the engine.

As an example, consider that the distance **B** between the center of the brake pulley and the portion of the beam resting on the scale is 4 feet. The circumference of a circle of this radius would be $2 \times 4 \times 3.1416$ which equals 25.1328 feet. If the engine pulley is running 200

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revolutions per minute and the lift on the scales is 100 pounds, we have the following expression:

$$\frac{25.13 \times 200 \times 100}{33{,}000} = 15.23 \text{ horse-power.}$$

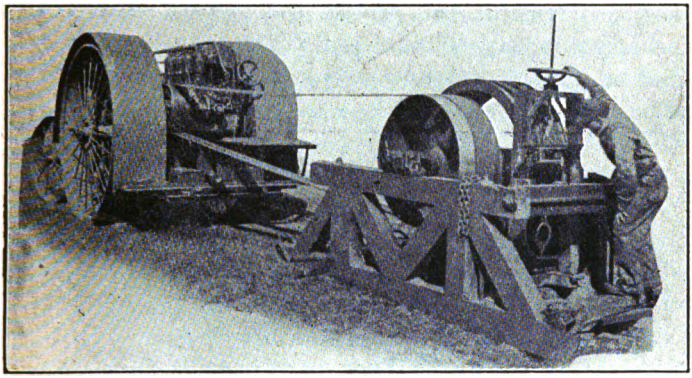

FIG. 21.—Making a Brake Test in the Field.

At Fig. 21 the method of making a brake test of a tractor power plant in the field is clearly indicated.

Drawbar horse-power is the amount of power actually exerted in doing useful work, such as in hauling. We have seen that the difference between indicated horse-power and brake horse-power represented the amount of power lost by friction in the engine. If we deduct the power lost by friction in the power transmission mechanism, owing to transmitting it through bearings and gears, and the power necessary in propelling the tractor itself over the ground from the brake horse-power at the pulley, we obtain the drawbar horse-power.

This cannot be determined as accurately and as easily as brake horse-power because it depends to a considerable degree upon the condition of the ground and the

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adhesion between the driving wheels of the tractor and the surface over which they are moving. Under favorable conditions where the slip is very slight, the drawbar horse-power of a well-designed gas tractor would be about ⅔ of the actual brake horse-power. It will not be as high as this unless the power-transmission mechanism is very efficient and the weight distribution, wheel and gear construction is such as to get the most perfect tractive effort.

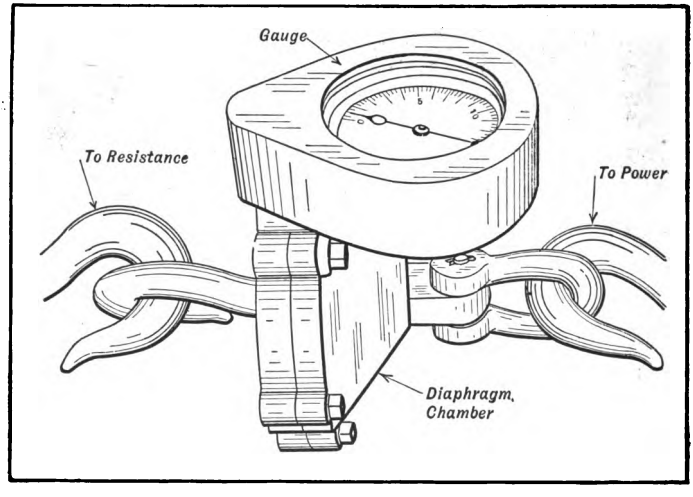

FIG. 22.—The Kennerson Traction Dynamometer, an Efficient and Simple Instrument for Measuring Draft.

The drawbar pull of a tractor is determined by means of some form of traction dynamometer, such as shown at Fig. 22. This instrument is placed between the source of power or drawbar of the tractor and some immovable body, such as a large tree. The tractor is started and the maximum amount of pull is indicated in pounds upon the gage just before the tractor-wheels

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slip or the engine stops. This dynamometer may also be used to indicate the tension in tow line or draft gear. As will be apparent, an instrument of this nature may be used very easily in making comparative tests between the tractive power or drawbar pull of various forms of engine and will also indicate the amount of draft needed to haul a wagon, pull a plough or do any other work.

The most easily understood rating, and one generally used in describing a tractor to the average farmer is the horse equivalent horse-power. This enables one who wishes to know how the work of a tractor will compare with the actual work of farm horses to make an intelligent approximation. It is difficult to make exact comparisons inasmuch as no two horses can do exactly the same amount of work, and furthermore the average animal is more flexible in its exertions than any mechnical tractor. We have seen that the horse is able to exert two or three times its average power for a short distance in the field, while a tractor has no such great overload capacity.

The horse equivalent power of a tractor is considerably less than its drawbar horse-power and represents the number of actual average farm horses that a tractor can replace in every-day work. It may be approximated by dividing the drawbar pull, exerted by a tractor travelling at two miles an hour by 200. If the tractor shows a drawbar pull of 2,000 pounds at that speed its drawbar horse-power or horse equivalent power will be equal to that produced by ten animals of average size.

Types of Gas Engines.—Two types of gas engines have been applied generally to furnish power for transportation purposes. These differ in construction and operating cycle to some extent, though in all forms power is obtained by the direct combustion of fuel in the cylin-

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ders of the engine. In all standard engines a member known as the piston travels back and forth in the cylinder with what is known as a reciprocating motion, and this in turn is changed into a rotary motion by suitable mechanical means to be described fully in proper se-

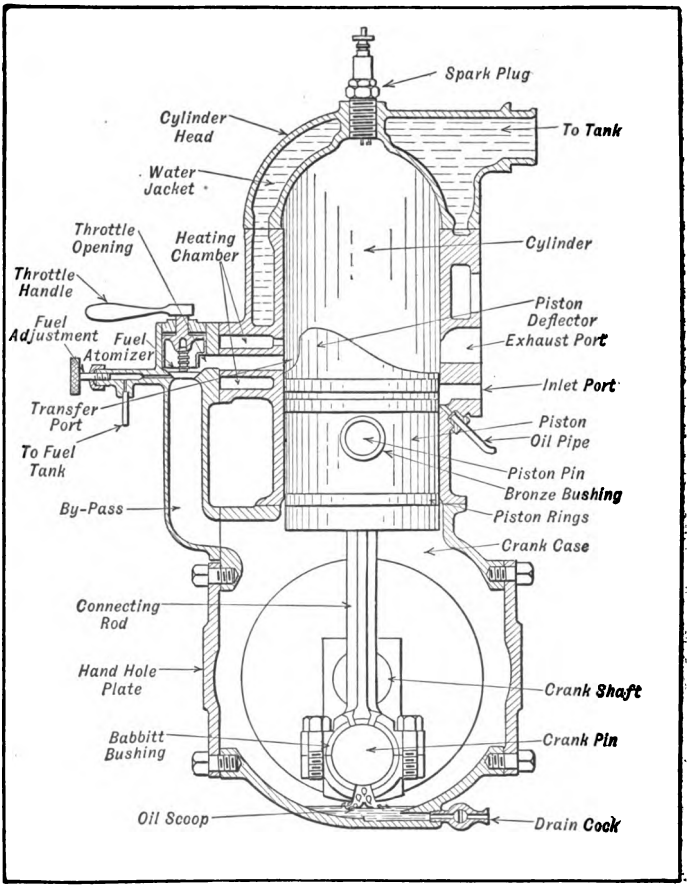

FIG. 23.—Sectional View of Ellis Three-Port, Two-Cycle Engine, Showing All Important Parts.

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quence. Gas engines may operate on either the two-cycle or four-cycle principle, the former being the simplest in action, though the latter is easiest to understand.

Comparing Two and Four-stroke Power Plants.—The sectional view of a two-cycle engine depicted at Fig. 23 shows the three moving parts employed. The gas is introduced into the cylinder and expelled from it through ports cored into the cylinder walls, which are covered by the piston at a certain portion of its travel and uncovered at other portions of the stroke. The three moving parts are the piston, connecting rod and crankshaft. If this type of power plant is compared with the four-cycle engine shown at Fig. 24 it will be apparent that it is much simpler in construction.

In the four-cycle engine the gas is admitted into the cylinder, through a port at the head closed by a valve, while the exhaust gas is expelled through another port controlled in a similar manner. These valves must be operated by mechanism distinct from the piston. In addition to the three main moving parts used in the two-cycle engine there are a number of auxiliary moving members that are part of the valve-operating mechanism. The four-cycle engine is more widely used because it is the most efficient type. The two-cycle engine is simpler to operate and very smooth running but it is not as economical as the four-cycle because a portion of the fresh gas taken into the cylinder is expelled through the open exhaust port with the burnt gases before it has a chance to ignite. As a four-cycle engine is more generally used its method of operation will be described first.

Operating Principles of Four-cycle Engines.—The action of the four-cycle type will be easily understood if one refers to the illustrations at Figs. 25 and 26.

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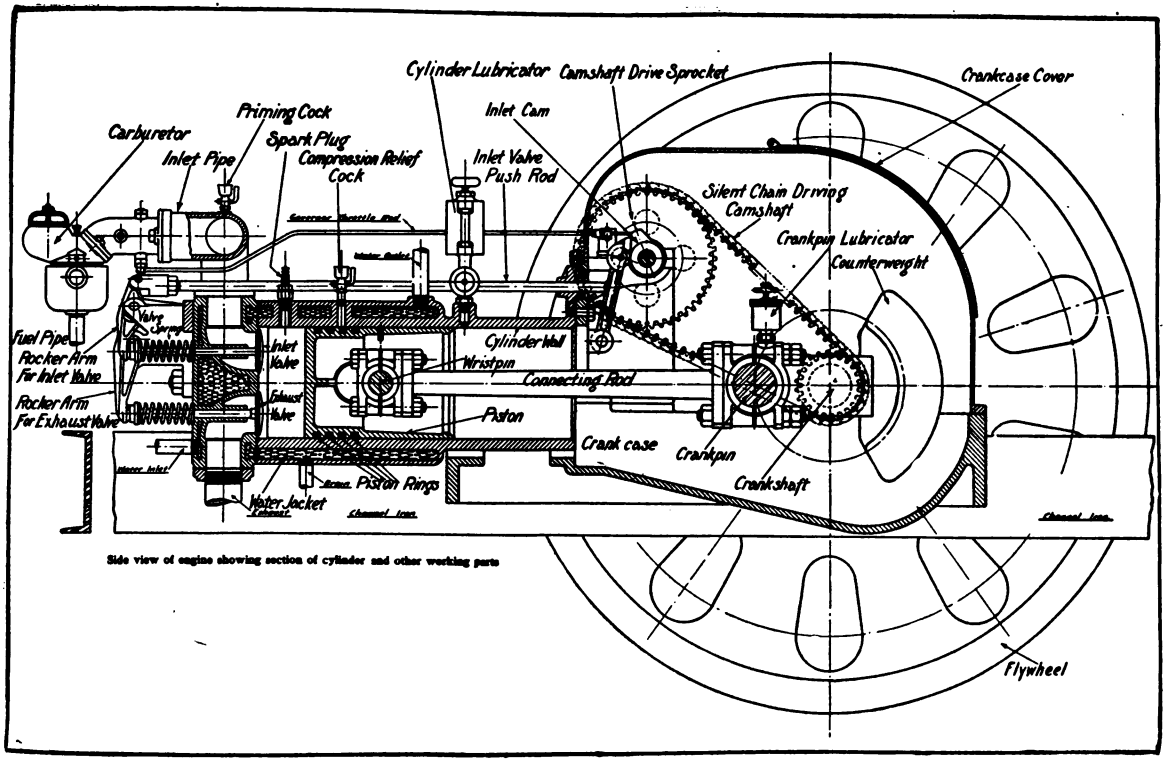

FIG. 24.—Longitudinal Sectional View of Four-Cycle Engine of Ohio Tractor, With Working Parts Clearly Indicated.

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It is called a four-stroke engine because the piston must make four strokes in the cylinder for each explosion or power impulse obtained. The principle of a gas engine is similar to that of a gun, i. e., power is obtained by a rapid combustion of some explosive or other quick-burning substance. The bullet is driven out of a gun barrel by the powerful gases liberated when the charge of powder is ignited. The piston of a gas engine is driven toward the open end of a cylinder by the expansion of gases resulting from combustion.

The first operation in firing a gun or securing an explosion in the cylinder of a gas engine is to fill the combustion space with combustible material. The second operation is to compress this and after compression, if the charge is ignited, the third operation of the cycle will be performed. In the case of the gun the bullet will be driven out of the barrel, while the piston of the gas engine will be forced toward the open end of the cylinder. As the bullet leaves the mouth of the gun the barrel is automatically cleared of the burnt powder gases which escaped to the outer air because of their pressure. The gun must be thoroughly cleared before the introduction of a new charge of powder. In a gas engine the fourth operation or exhaust stroke is performed by the return stroke of the piston.

The parts of a simple engine have been previously indicated, and in order to better understand the action it will be well to consider briefly the various parts and their functions. The cylinder is an important member because it is in this portion that practically all the work is accomplished. The cylinder is provided with three ports, one through which the gas is admitted, controlled by an inlet valve, another through which the burnt gas is expelled, closed by the exhaust valve, and the third in

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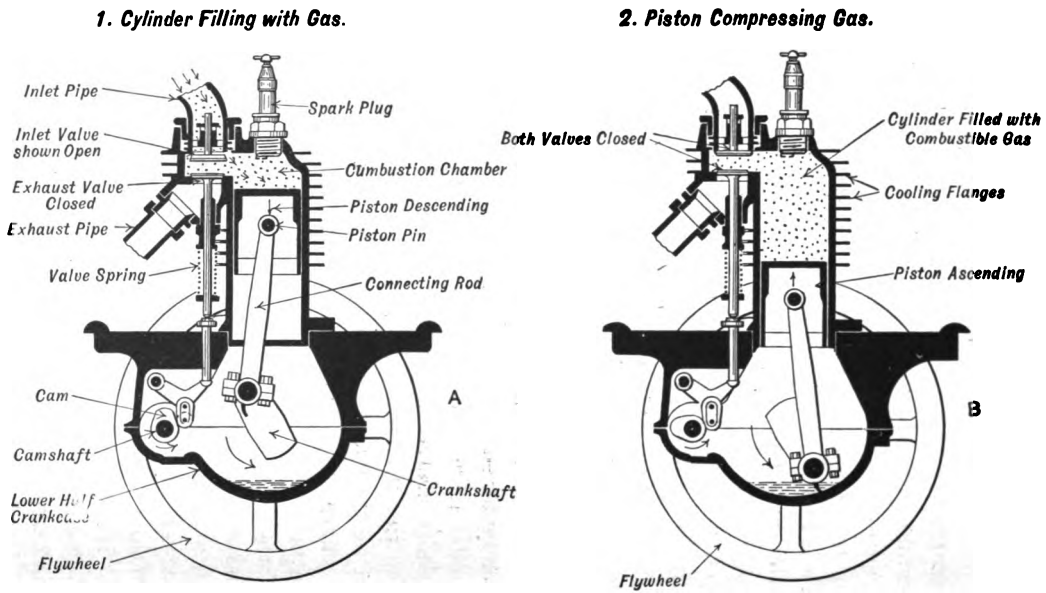

FIG. 25.—Views of Simple Four-Cycle Engine Showing Methods of Charging Cylinder With Explosive Gas and Compressing It Prior to Ignition.

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which the spark plug used to ignite the compressed gas is screwed. The reciprocating motion of the piston, which is the member moving up and down in the cylinder, is transformed into a rotary motion of the crank shaft by means of a connecting rod and crank pin.

In the simple engine shown at Figs 25 and 26 the inlet valve is an automatic one, while the exhaust member is raised from its seat by a mechanism including the camshaft, cam, valve-operating bell crank and plunger. At Fig. 25-A the piston is starting to go down on the first stroke of the four necessary to produce a complete cycle of operations. As the piston descends it creates a suction in the combustion chamber, the automatic valve is drawn down from its seat and a resh charge of gas is drawn into the cylinder through the inlet pipe which communicates with the gas-supply device or carburetor. The inlet valve will remain open until the piston reaches the bottom of its stroke. As soon as the pressure inside the cylinder is equal to that outside which condition obtains as soon as the piston has reached the end of its downward stroke and the cylinder is filled with gas the inlet valve is closed and the piston starts to return on the next stroke as shown at Fig. 25-B.

As both valves are closed the combustible vapor with which the cylinder is filled is compressed into a much smaller volume. The reason for compression is that any agent which gives out energy through the expansion of gases is rendered more efficient by confining it in a restricted space and directing the whole energy against some one spot. A tuft of gun cotton could be ignited while lying loosely in the hand and it would burn freely but without explosion. If it is confined in a gun barrel and exploded it will drive the bullet out with a great amount of force or burst the metal walls of the con-

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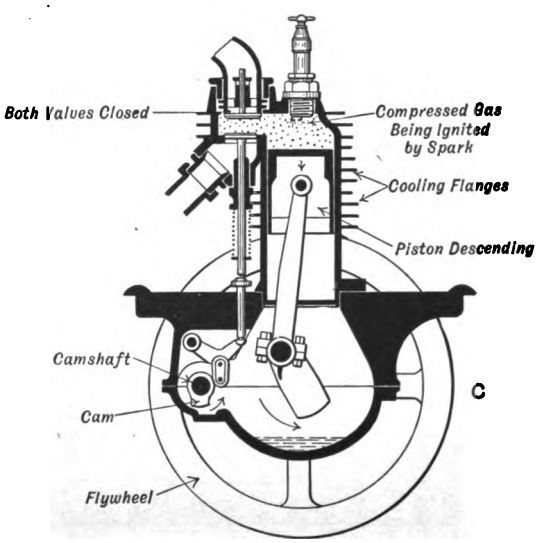

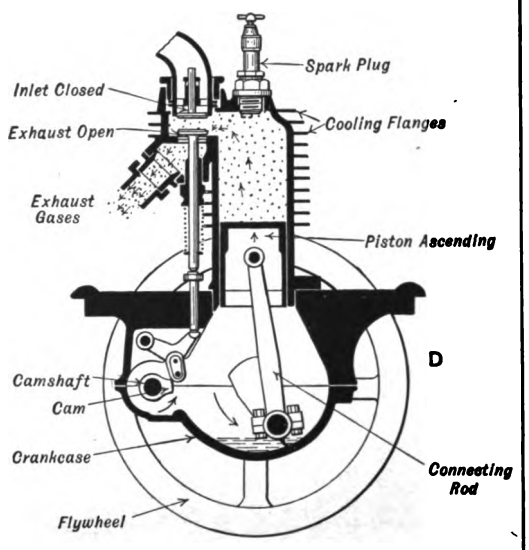

FIG. 26.—Views of Simple Four-Cycle Engine Showing Effect of Explosion and How Burnt Gases are Exhausted From Cylinder.

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tainer. Gasoline vapor and air will ignite and burn freely at atmospheric pressure and a gasoline engine could be made to run without compression. The expansion of the unconfined gases would not be great enough to do effective work, however, and the fullest efficiency of the fuel is obtained by compacting it into the smallest possible space and then igniting it at the instant when it is compressed the most.

Any chemical action requires close contact between the materials producing it, if it is to occur under the most favorable conditions. That which occurs when a mixture of gasoline vapor and air are brought into contact with the flame or arc of the electric spark is practically instantaneous if the gases are crowded together. If the gas is not properly compressed, the action becomes more dilatory, extending to a slow combustion wherein the temperature is not raised enough to expand the gases efficiently as the degree of compression is lessened. A good example of slow combustion is the decay of wood, while the phenomenon that we call "burning" may be taken as an illustration of quick combustion. It is said that the same amount of heat is produced by either combustion but only the latter produces it quickly enough to be noticeable.

The comparatively slow combustion of the gases in the engine cylinder, when at atmospheric pressure would not permit the energy derived from the heat to act all at once. When the gases are compressed the particles of vapor are in such intimate contact that combustion is practically instantaneous and the gases give off maximum energy by expanding their utmost due to the high temperature developed. The piston is also in a position to be acted upon most readily as the force due to pressure of the gas is directly against it and not exerted through

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an elastic cushion of half-ignited gas as would be the case if the charge was not compressed before ignition.

When the piston reaches the top of its second stroke the compressed gas is exploded by means of an electric spark between the points of the spark plug and the piston is driven down toward the open end of the cylinder, as indicated at Fig. 26-C. At the end of this down stroke the pressure of the gases is reduced to such a point that they no longer have any value in producing power. At this time the cam, which is operated in timed relation to the crank-shaft travel, raises the exhaust valve from its seat and the burnt gases are expelled through the open exhaust port until the cylinder is practically cleared of the inert products of combustion, the natural scavenging action being assisted by an upward movement of the piston. The piston once more begins to descend, as shown at Fig. 25-A and the inlet valve opens to admit a new charge. The rest of the cycle of operations follow in the order indicated and are repeated as long as the cylinder is supplied with gas and this is ignited.

How Two-cycle Engines Work.—The two-cycle engine works on a different principle, as while only the combustion chamber end of the piston is employed to do useful work in the four-cycle engine, both upper and lower ends are called upon to perform the functions necessary to two-cycle engine operation. Instead of the gas being admitted into the cylinder, as is the case with the four-cycle engine, it is first drawn into the engine base, where it receives a preliminary compression, prior to its transfer to the working end of the cylinder.

The views at Fig. 27 show clearly the operation of a two-port, two-cycle engine. Assuming that a charge of gas has just been compressed in the cylinder and that the upward movement of the piston while compressing the

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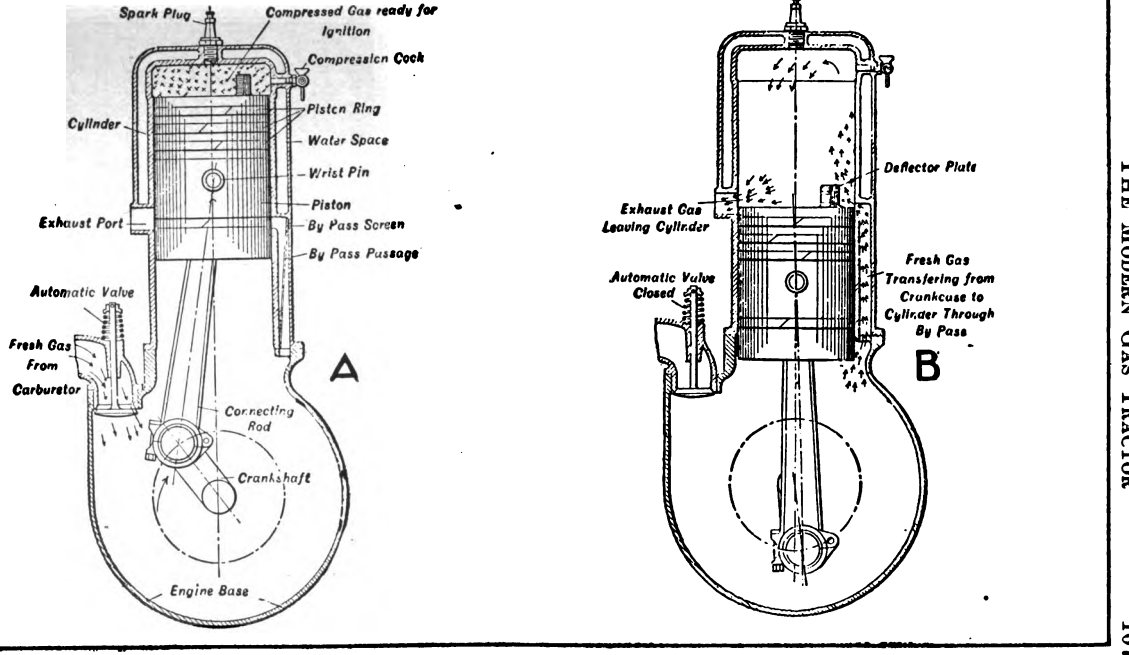

FIG. 27.—Defining Action of Two-Port Two-Cycle Motor.

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gas above it has drawn in a charge through the automatic intake valve in the crank case, it will be apparant that as soon as the piston reaches the top of its stroke and the gas has been properly compressed that the explosion of this charge by an electric spark will produce power in just the same manner as it does in the four-cycle motor. As the piston descends due to the impact of the expanding gases, it closes the automatic inlet valve in the crank case and compresses the gases confined therein.

When the piston reaches the bottom of the cylinder it uncovers the exhaust port cored in the cylinder walls and the burnt gases leave the cylinder because of their pressure. A little further downward movement of the piston uncovers the intake port, which is joined to the crank case by a by-pass passage, at which time a condition exists as indicated at Fig. 27-B. The piston has reached the bottom of its stroke and both exhaust and inlet ports are open. The burnt gases are flowing out of the cylinder through the open exhaust port, while the fresh gases are being transferred from the crank case, where they had been confined under pressure to the cylinder. The fresh gas is kept from passing out of the open exhaust port opposite the inlet opening by a deflector plate cast on the piston head, which directs the entering stream of fresh gas to the top of the cylinder.

As the piston goes back on its up stroke the exhaust and inlet ports are closed by the piston wall and the charge of gas is compressed prior to ignition. As the piston travels up on its compression stroke, the inlet valve in the crank case opens, due to the suction produced by the piston and admits a charge of gas, through the open crank case intake port. It will be seen that an explosion is obtained every two strokes of the piston

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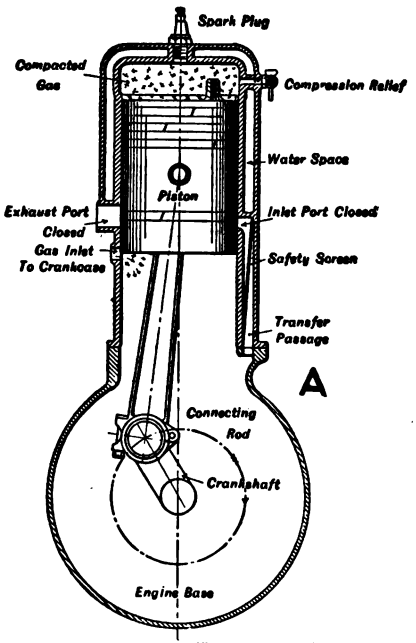

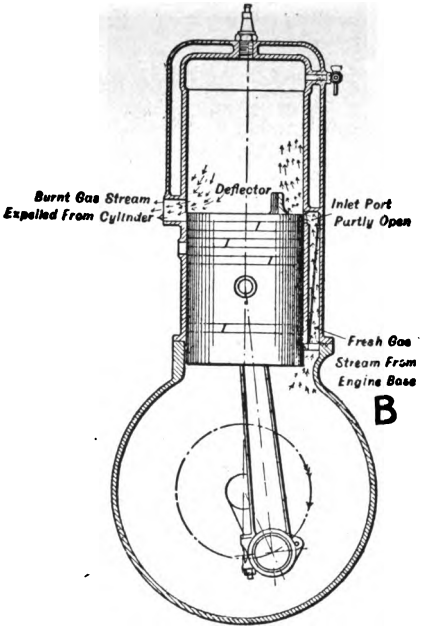

FIG. 28.—How Three-Port Two-Cycle Engine Operates.

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instead of every four strokes, as is the case with a four-cycle engine. In the two-cycle form one explosion is obtained for each revolution of the crank shaft, while in the four-cycle two revolutions of the crank shaft are necessary to obtain one power impulse.

The operating principle of the three-port two-cycle engine outlined at Fig. 28 is just the same as that previously described except that the gas from the carburetor is admitted to the crank chamber through a small port in the cylinder wall, which is open when the piston reaches the top of the stroke as shown at A. The three-port method of construction makes it possible to dispense with the automatic inlet valve shown in Fig. 27, and an engine of this kind is a true valveless type.

Advantages of One-cylinder Motors.—As the first power plants developed for general use were of the one-cylinder pattern and this type motor has been improved to a point where it is very efficient it is but natural that the first gas tractors would utilize the perfected one-cylinder engine then so widely used for farm power in stationary installations. It was not a difficult matter for the designer of the early gas tractor to take a running gear and driving mechanism, similar to that employed in steam tractors and to replace the boiler and steam engine with a horizontal single-cylinder stationary form of power plant. A typical one-cylinder motor of the horizontal type such as used on the lighter I. H. C. gas tractors is shown at Fig. 29.

The single-cylinder engine offers a main advantage of extreme simplicity. This is of considerable importance in the lighter all-purpose tractors that are to be operated by inexperienced help. Among some of the disadvantages that may be cited against the single-cylinder power plant are great weight in proportion to

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power developed, lack of even power application because only one stroke out of four made by the piston is effective. A one-cylinder engine lacks the even turning movement and steady running qualities that a multiple cylinder power plant possesses. If run faster or slower

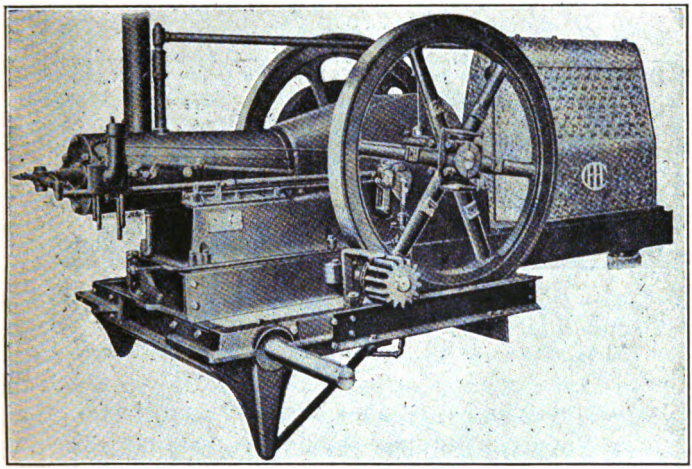

FIG. 29.—Single Cylinder Power Plant Used on I. H. C. Two Speed Light Tractor.

than the critical speed for which it is designed there will be considerable vibration. Despite these faults, the single-cylinder engine is very practical in applications to light, slow-speed tractors.

Features of Multiple Cylinder Motors.—Power is obtained in the multiple cylinder motor by using a number of cylinders instead of one large member. The cylinders are arranged in such a way that any multiple-cylinder motor may be considered as a number of single-cylinder engines joined together so that one cylinder starts to deliver power to the crankshaft where the

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other leaves off. By using a number of smaller cylinders instead of a large one all of the revolving parts may be made lighter and the reciprocating members are easier to balance because the weight of the parts in one cylinder often counter-balances the reciprocating mass in the other that works in connection with it.

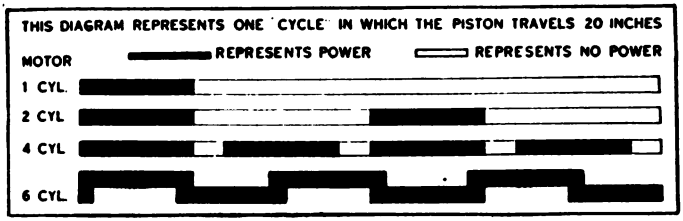

FIG. 30.—Diagram Showing Advantages of Multiple Cylinder Motors and Why They Deliver Power More Evenly Than Single Cylinder Types.

Multiple-cylinder engines may be run faster than single-cylinder ones of the same power, are not so heavy in proportion to the power developed and produce a more even turning effect at the crankshaft. No matter how well designed the single-cylinder power plant is, the power impulses will come in jerks, and a very heavy fly-wheel member, or pair of fly-wheel members is needed to equalize the intermittent power strokes. In a multiple-cylinder engine where the explosions follow each other in rapid succession the power application is obviously much more even. A single-cylinder engine will give but one useful power stroke when of the four-cycle type, to every two revolutions of the crankshaft. A two-cylinder motor will give one explosion every revolution, while a three-cylinder power plant will give three explosions every two revolutions.

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The real value of a multiple-cylinder motor is more apparent when four or six cylinders are used because in the former one obtains a power impulse every half revolution of the fly-wheel, while in the latter three-power strokes are delivered every revolution. The diagram presented at Fig. 30 compares in a graphic manner the useful power impulse of engines having a cycle in which the piston travels twenty inches. The shaded parts represent periods where power application obtains, while the unshaded portions represent no power. In the one-cylinder engine it will be evident that less than one-quarter of the cycle represents useful energy. In the two-cylinder engine the explosions are evenly spaced but are separated by appreciable spaces where no power is developed.

Even in the four-cylinder engine there are periods (corresponding to the early opening of the exhaust valves on the power stroke) where no useful energy is directed against the crank shaft. The torque, or power application is uniform enough for all practical purposes, except where the utmost refinement is desired, as in high-grade motor car power plants. In the six-cylinder engine, however, there are no periods in the cycle of operation where the crank shaft is not positively driven. In fact, the explosions overlap each other and a very smooth-acting power plant is obtained. For tractor service, however, a four-cylinder motor will prove to be very satisfactory and will operate with minimum vibration.

Heavy Duty and Medium Duty Engines.—It is possible to divide the multiple-cylinder motor class into two general groups. One will include all engines having horizontally disposed cylinders, while the other group will be composed of power plants having vertical cylinders. The horizontal group may be divided into sub-

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divisions, where some of the motors will have the cylinders on one side of the crank shaft and the other where half of them are on one side and half on the other side of crank-shaft center. The form in which the two cylinders are placed side by side is preferred because of compactness, though this advantage is counteracted by difficulties which obtain in proper balancing. Where the cylinders are opposed the tendency to vibration is neutralized because a better balance of reciprocating parts is obtained and the explosions follow in regular sequence. The vertical motor has a number of advantages over the horizontal type. There is less liability of the cylinder walls wearing out of round and it is easier to lubricate the cylinder when the head is at the top. As a rule, multiple-cylinder engines of the vertical type are much more compact and easier placed on the tractor frame than horizontal engines of the same power and number of cylinders would be.

Tractor power plants are often referred to as medium-duty or heavy-duty engines. The heavy-duty type is one where all the bearings and working parts have been proportioned unusually large. It is believed these engines are more suitable for continuous duty at full load than the lighter engines where the bearings are not so large. This is apt to prove confusing, however, because many engines considered heavy-duty power plants must be built very heavy to withstand the vibration and stress present while they are in operation. Many medium-duty engines would be capable of doing more work and operate for a longer period than power plants where the reciprocating and rotating members were very much larger.

Reciprocating parts produce strains and vibration no matter how perfectly an engine is balanced and the

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extent of these stresses is dependent on the weight of the moving parts and the piston velocity. In order to prevent undue depreciation heavy-duty engines which have large parts must operate at a slower speed than the medium-duty power plants where the weight of the reciprocating masses is less. Heavy-duty engines are usually of the horizontal type and have one or two cylin-

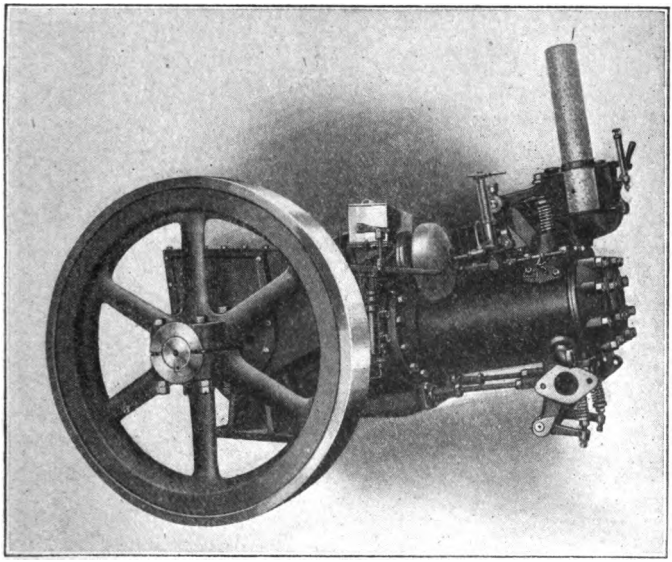

FIG. 31.—Fly Wheel Side of Two Cylinder Horizontal Motor Used in "Oil Pull" Tractors.

ders, while the medium-duty types are almost invariably of the four-cylinder vertical pattern.

In the vertical motor of the four-cylinder type the parts may be made lighter than in the other forms and as the weight of the piston and connecting rod is entirely removed from the walls of the cylinder, these parts

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practically float in a film of oil and the weight is carried in such a way that the least wear is imposed on the cylinder walls, the piston and piston rings. The load is carried by the easily adjusted main bearings of the engine rather than the cylinder, which can be restored to true bore when worn only at considerable expense.

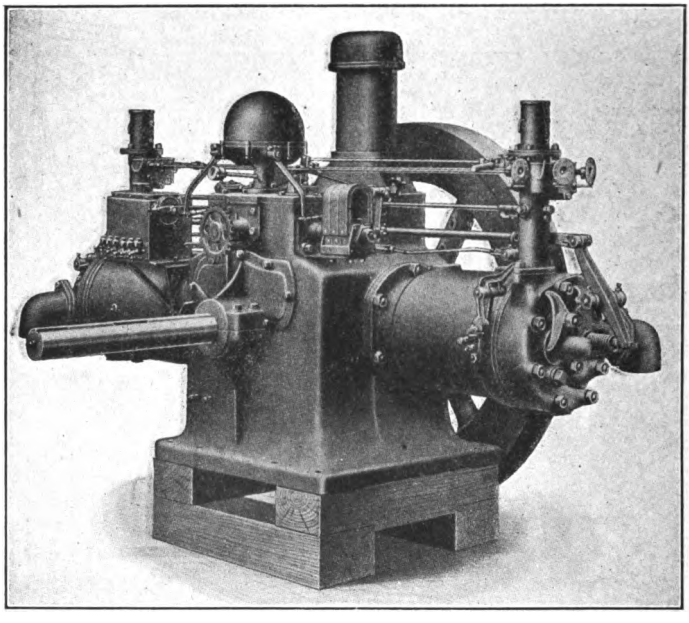

FIG. 32.—Double Opposed Motor of 45 Horse-power Used on I. H. C. Mogul Tractor.

The vertical motor construction makes it possible to use a very efficient lubricating system and the difficulty that obtains in a horizontal engine of flooding the cylinder head with oil is not present in the vertical cylinder. The oil is also more evenly distributed in a vertical motor because there is no tendency for it to collect at

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the lowest point, which is the wall of the cylinder directly under the piston of the horizontal engine.

Another advantage of the vertical cylinder construction is that the vibratory stresses travel in vertical lines and are resisted by parts best adapted to receive them as the axles and wheels. In a horizontal motor, vibration must be absorbed by the frame and gearing and considerable stress is placed on parts not well adapted to resist them. It is not the writers intention to contend that horizontal motors are not practical, but it is evident that where these are used the frame parts and gearing must be heavier because they are called upon to take vibratory stresses as well as carry the weight of the engine. As a rule the vertical cylinder motor is more accessible than the horizontal engine. The vital parts which need more or less attention, such as the valves, spark plugs, ignition wiring, water piping, etc., are more easily reached than in the horizontally disposed power plant. Either a medium-duty or heavy-duty engine is suitable for tractor propulsion, though the preference of most designers is for the former because of the advantages previously enumerated.

One-cylinder Tractor Engines.—The construction of a typical one-cylinder tractor power plant can be easily understood by referring to Fig. 29. The motor is a long-stroke, heavy-duty type with an inclosed crank case. The cylinder is supported by a substantial cast-iron bed, which in turn is attached to the substantial I beams, forming the main frame members. The fly-wheels are large and are mounted one on each side of the crank shaft. The heavy fly-wheels are necessary to equalize the intermittent power application and are arranged in the manner indicated in order to distribute the twisting strain evenly on the crank shaft. If one

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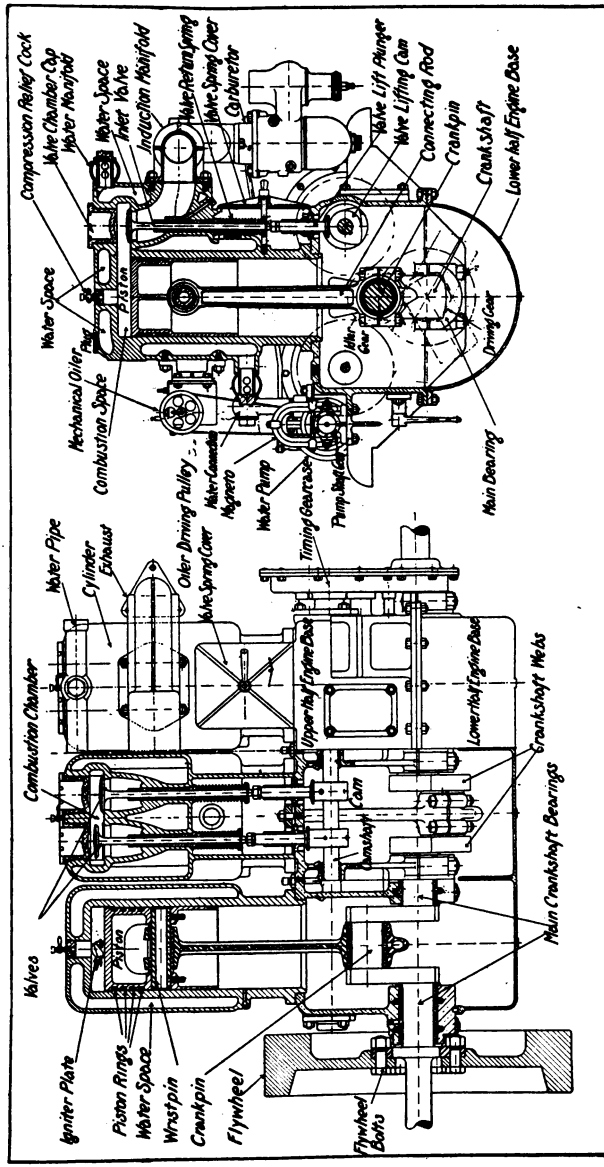

FIG. 33.—Sectional Views of Three Cylinder Vertical Motor, Forming Power Plant of One Model of Russell Gas Tractor.

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large wheel was carried at one side of the motor, equal in weight to the two fly-wheels, then the crank shaft would have to be strengthened very much on the fly-wheel side to resist the twisting strain resulting from the heavy rim of the fly-wheel. In practically all stationary and tractor power plants of the single-cylinder type where the fly-wheel mass is great it is common practice to mount one fly-wheel at each side of the motor base. The valves, which admit the gas to the cylinder and provide for the expulsion of the burnt products of combustion are carried in a detachable cylinder head at the back end of the motor. In this construction every effort has been made to have the parts accessible and the engine shown is one of the most practical single-cylinder types which has demonstrated its worth in many different applications.

Two-cylinder Tractor Engine.—Two forms of double-cylinder motors, commonly used in tractor work are shown at Figs. 31 and 32. That at Fig. 31 is a form in which the cylinders are horizontally disposed but mounted side by side at one side of crank-shaft center. The magneto, oiler, and other parts are placed on top of the engine base, where they will be easily reached. In motors of this type either the explosions will not be separated by regular intervals or the mechanical balance will be poor. If it is intended to have the weight of one piston counter-balance that of the other, and crank pins are spaced at 180 degrees to attain this end, then the explosions will follow one right after the other, which will result in two explosions occurring during one revolution of the fly-wheel and no explosion during the other revolution. Instead of being separated by intervals of 180 degrees, the explosions will be separated by intervals of 90 degrees and 270 degrees respectively. At the

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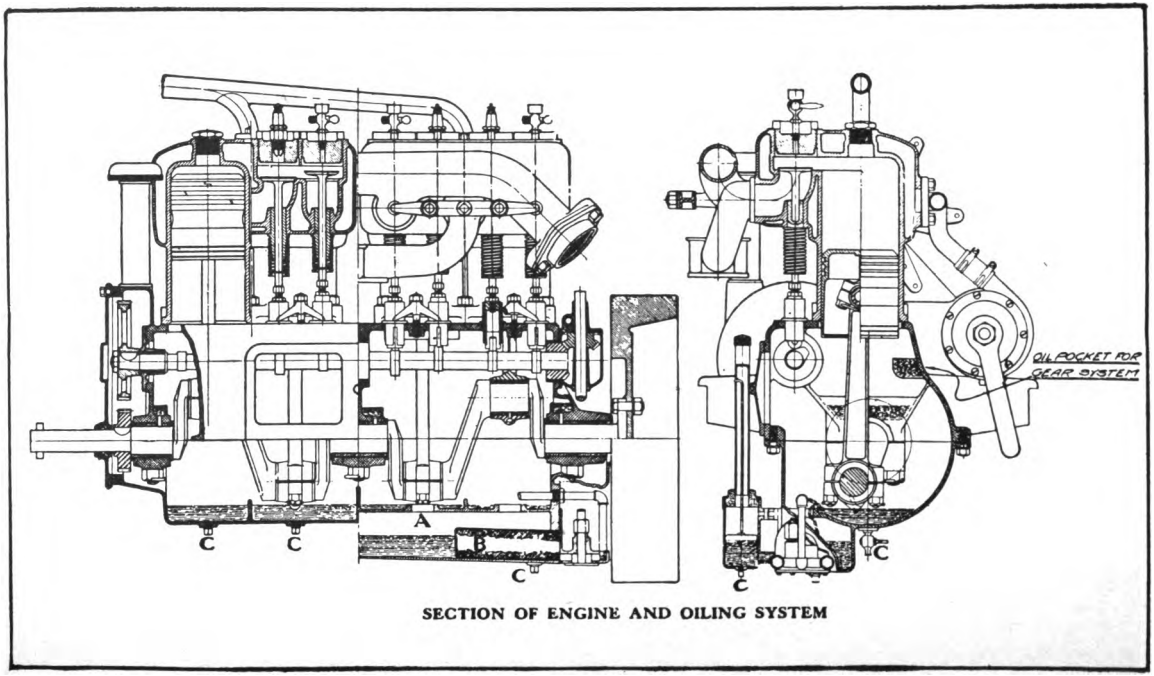

FIG. 34.—Sectional Views of Typical Four-Cylinder Tractor Motor That Follows Automobile Practice.

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other hand, if the two crank pins are on the same plane and both pistons move in and out of their respective cylinders together, it will be necessary to counter-balance the crank shaft just as though the engine was a single-cylinder form. The explosions will be evenly spaced, however, and will be separated by an interval of 180 degrees. One will take place during the first half of the first revolution of the fly-wheel, while the other will take place the first half of the second revolution.

The opposed power plant shown at Fig. 32 is a form generally favored by designers when two-cylinder engines are employed. By carrying one cylinder at each side of the crank shaft center it is possible to secure a better balance of the reciprocating parts and the crank shaft does not need to be counter-balanced. A lighter fly-wheel can be used than on the two-cylinder unit type and the explosions are evenly spaced. The disadvantage of this form of motor is that it usually is long and occupies the greater part of the available space on the tractor frame. Both of the two-cylinder engines shown are practical and have been used successfully.

Three-cylinder Power Plants.—The three-cylinder motor is a type that is very seldom used because most designers prefer stepping directly to the four-cylinder from the simpler two-cylinder types. In a three-cylinder power plant the crank pins are arranged on thirds of the circle or 120 degrees apart. Such an engine is usually very satisfactory in action as regards vibration and evenness of torque. The reciprocating members are well balanced and the explosions follow in regular sequence. While the mechanical balance is not as good as that obtaining in a four-cylinder power plant it is much superior to that prevailing in two-cylinder engines. The regular sequence of explosions makes it deliver

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power more uniformly than a two-cylinder, though it does not deliver as steady power as a four-cylinder. A typical three-cylinder tractor power plant is shown in section at Fig. 33, and as all parts are clearly indicated further description is not necessary. Three-cylinder power plants have not received the wide application that

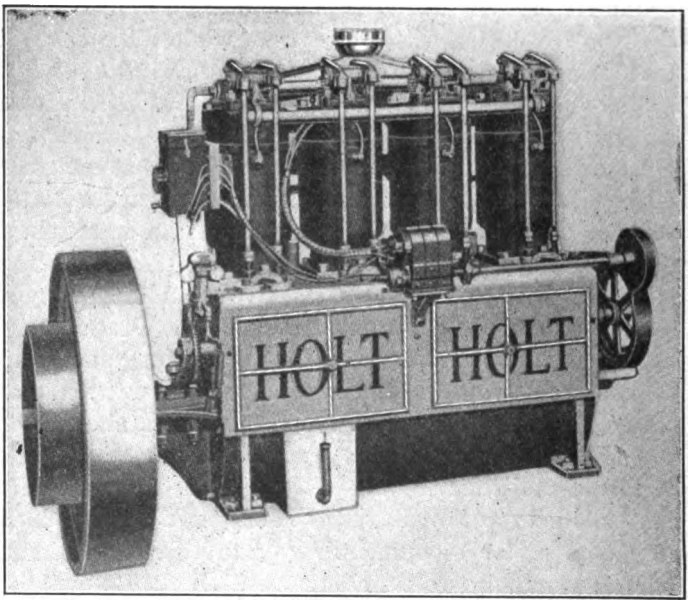

FIG. 35.—The Holt Four Cylinder Power Plant With Valves Opening Directly Into the Cylinder Heads.

the four-cylinder type have and are used on only one prominent make of tractor to the writer's knowledge.

Four-cylinder Motors.—The four-cylinder power plant is the type that is now practically universal in motor-car practice for all light and medium weight cars. Many of the tractors now on the market are equipped with four-cylinder power plants because these offer

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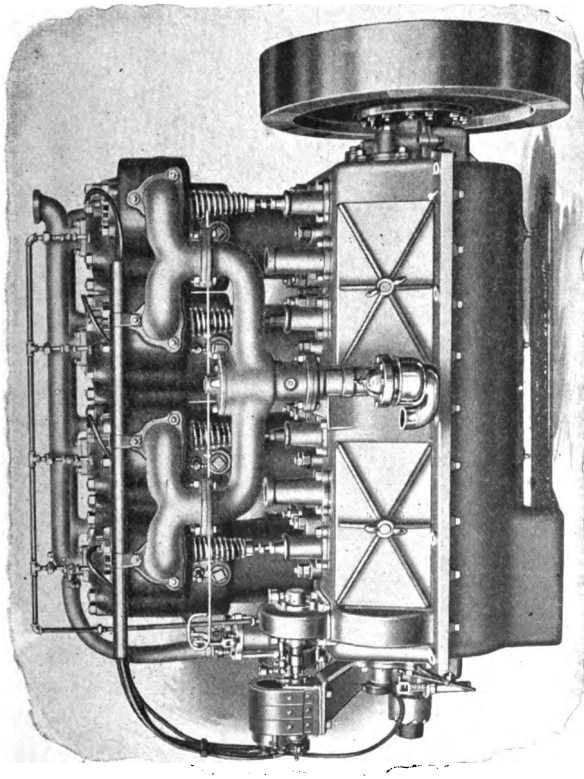

FIG. 36.—Four Cylinder Engine Used On "Tiger Pull" Tractors.

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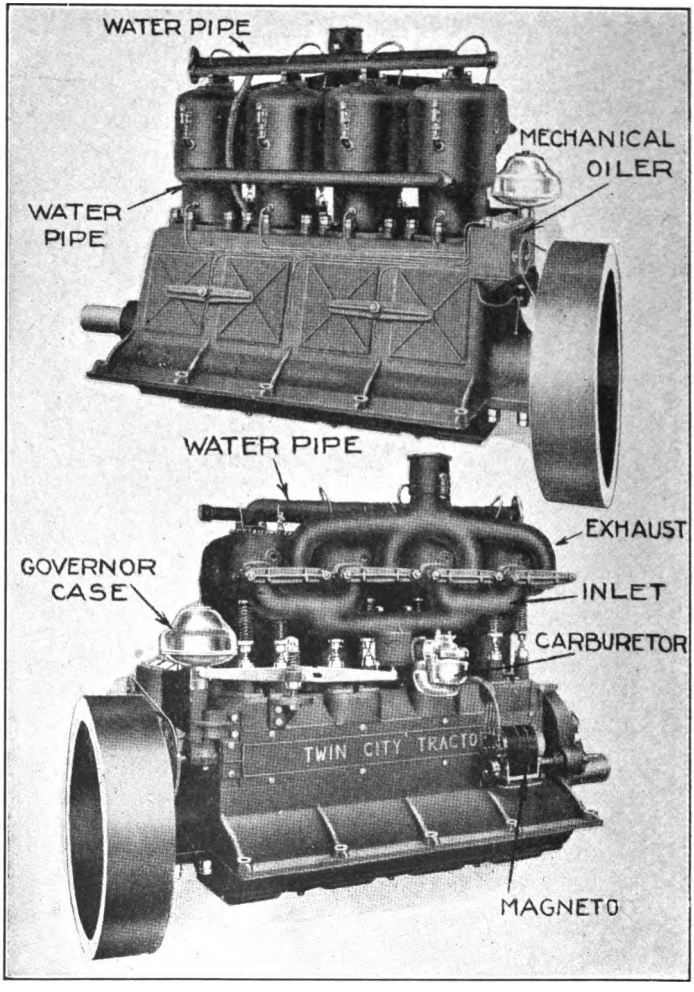

FIG. 37.—Views of Well Designed Four Cylinder Power Plant Used in "Twin City" Gas Tractor. Top View Shows Water Manifolds and Mechanical Oiler; Bottom View Presents Valve Side and Shows Induction and Exhaust Manifolds, Carburetor and Magneto.

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every practical advantage that is needed, and more nearly fill the requirements of the ideal tractor power plant than do the simpler one, two or three-cylinder types.

A typical cross section of a four-cylinder engine of the automobile type which has been applied as a tractor power plant is shown at Fig. 34. It will be evident that the four cylinders are placed tandem on a common crank case. The crank shaft has four throws, one for each cylinder and three main bearings. One of the bearings is at the center between the two pairs of cylinders, the other two bearings are at the front and rear end respectively. In the motor shown the first and fourth pistons travel together while the second and third pistons move at the same time.

The compactness of this type of power plant can be well understood. As will be seen one cam shaft serves to operate all the valves, and connections are easily made for the inlet and exhaust manifolds and water piping. A four-cylinder vertical engine designed especially for tractor use is shown at Fig. 35, and is composed of four individual cylinder castings of the valve-in-the-head type, instead of the two twin cylinder castings of the valve at one side type previously illustrated.

Two other practical four-cylinder traction engines are shown at Figs. 36 and 37. In the latter two views of the motor are shown. The upper view clearly shows the method of installing the mechanical oiler on the crank case near the fly-wheel and depicts the oil leads running to the various cylinders and other bearing points. The large hand holes, which give access to the crank case interior are also indicated and their size may be judged by the cover plates, which serve to close them.

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The lower view is the valve side of the motor and shows clearly the governor case, the method of installing the magneto and carburetor, the design and method of securing inlet and exhaust manifolds and the location of the valves in pockets at the side of the L-shaped individual cylinder castings.

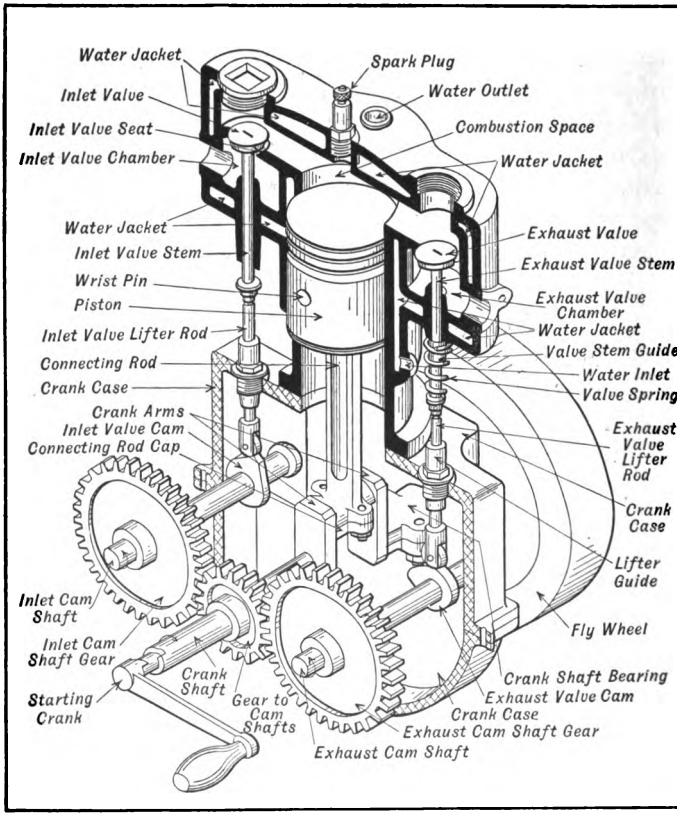

FIG. 38.—Single Cylinder Four-Cycle Motor With One Half of Cylinder and Crankcase Removed to Show All Important Parts.

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CHAPTER IV.

GAS TRACTOR POWER PLANT COMPONENTS.

Parts of Tractor Engines and Their Functions—Cylinder Construction—The Valve System—Piston and Rings—Connecting Rod Types—Crankshaft Forms—Utility of Flywheel—Engine Base and Bearings.

Parts of Tractor Engines and Their Functions.—The general design of tractor engines having been considered and the principles upon which their action is based outlined, it will be advisable to consider more in detail the various parts comprising the engine, the materials of which they are made, the various common forms they exist in and their functions. In the cross-sectional view of the typical four-cycle engine depicted at Fig. 38 all the important parts of a single-cylinder power plant are shown. In a four-cylinder engine most of these parts pertaining to the cylinder and valve operation would be multiplied by four, though one set of cam shafts and cam shaft gears, one engine base and crank shaft and one fly-wheel would be all that would be needed whether the engine has one or six cylinders. The parts of a multiple cylinder engine are thus duplicates of each other to a large extent and when the parts of one cylinder and their functions are understood, it will not be difficult to understand any four-cycle gas engine.

The cylinder, which is a "T" head form, having valves at both sides is attached to a base of aluminum in which the cam shafts and crank shaft are housed. The piston

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is the reciprocating member that moves back and forth in the cylinder and it is joined to the connecting rod by means of a wrist pin passing through the upper end of the connecting rod. The lower portion of the connecting rod is attached to the crank pin of the crank shaft. As the piston travels up and down in the cylinder it turns the crank pin just the same way as the reciprocating motion of a sewing-machine treadle is transformed to a turning movement of the large driving wheel. The cylinder is provided with a water jacket, which is a hollow space cored between the inner and outer walls through which water is circulated to keep the engine cool. The valves are carried in side pockets extending on each side of the cylinder and are held against their seats by means of coil springs.

The cam shafts, which turn the cams used to operate the valves are driven from a small gear on the crank shaft, the ratio of drive being two turns of the crank shaft for one turn of the cam shaft. In all four-cycle motors of conventional design regardless of the number of cylinders used the cam shafts always turn at one half crank shaft speed. The valves are raised from their seats by means of push rods, which transfer the motion imparted by the cam point raising the roll which bears against the cam. These members are steadied by guide bushings screwed into the engine crank case.

The starting crank is used to turn the crank shaft through the preliminary movements necessary for the piston to draw in a charge of explosive gas and compress it. When the gas is exploded by the electric spark which occurs between the points of the spark plug mounted in the cylinder head, the piston is driven down and a certain amount of the energy produced by the explosion is stored in the fly-wheel rim. As a general rule, after the

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first explosion, the engine will continue to run without hand cranking.

The inlet valve is used to admit the fresh gas from the carburetor to the combustion chamber and is raised from its seat when the piston starts to go down on the induction stroke. It remains open until the piston has reached the bottom of this stroke and the cylinder is filled with gas. While the piston has been going down the cam shaft has been turning and when the piston reaches the bottom of its stroke the cam point has revolved until it is out of contact with the roller in the valve plunger and the valve spring, which is not indicated but similar to that shown on the exhaust valve, returns the inlet valve to its seat in the valve chamber.

The exhaust valve does not open until the piston has made two more strokes, one the compression the other the expansion, or power stroke. When the piston has covered approximately seven-eights of its movement on the power stroke the exhaust cam turns around, raises the push rod, which in turn raises the exhaust valve from its seat, and permits the burnt gases to escape through the open exhaust port. The valve remains open during the entire upward stroke of the piston, closing when the piston reaches the top. The inlet cam has now come into action again and another fresh charge of gas is drawn into the cylinder during the beginning of the next cycle of operation. From the foregoing description it will not be difficult to understand the action of the various parts of the four-cycle engine and the relation these members bear to each other.

Cylinder Construction.—The cylinder is one of the most important parts of any form of heat engine and it is subjected to greater stress than any other member. As a rule cylinders are made of cast iron and unless of

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the air-cooled form have water jackets cast integral. Tractor engines of the usual pattern use individual cylinder castings, though some of the forms which are built according to automobile practice have the cylinders cast in pairs. Tractor engines are generally of large bore and long stroke because power is obtained by large piston displacement rather than high crank-shaft speed.

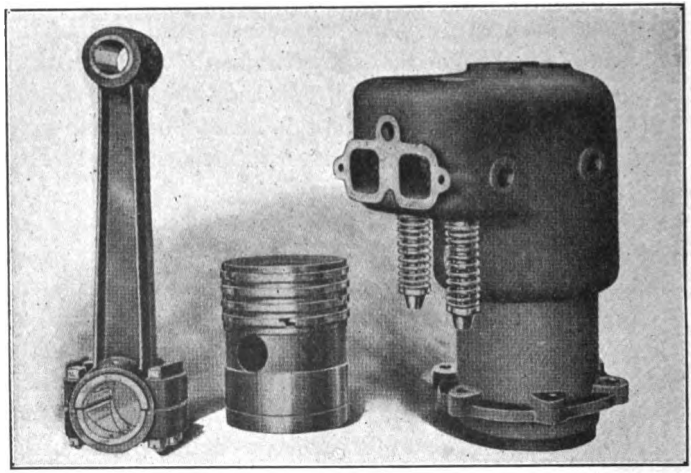

FIG. 39.—Cylinder With Both Valves on One Side, Four Ring Piston and Marine Type Connecting Rod.

The conventional form of gas-engine cylinder is outlined at Fig. 39 in connection with the piston and connecting rod. This cylinder is of the L form and has the water jacket cast integral. Both valves are carried at one side of the cylinder head which is a unit with the cylinder.

A cross-section through a cylinder of this form is shown at Fig. 40. The large water spaces surrounding the cylinder walls and combustion chamber are clearly indicated. The bore of the cylinder is finished very smoothly

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in order that the piston may slide up and down with minimum friction. Gas-engine cylinder castings are commonly given a preliminary boring cut and then are set away to age or season for a number of weeks before any more machine work is done on the casting. Sometimes cylinders are annealed before they are put away to

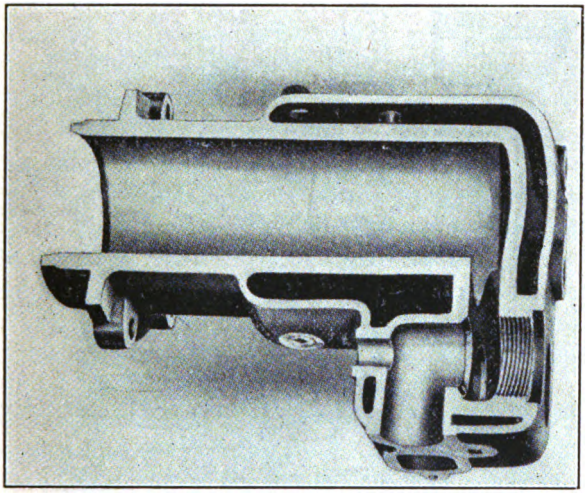

FIG. 40.—Sectional View of "L" Head Cylinder Showing Water Spaces Around Combustion and Valve Chamber.

age. The removal of the scale from the interior of the cylinder relieves some of the stresses produced in the metal when the cylinder was cast and the seasoning operation permits it to assume a definite shape. After aging the cylinders may be finish-bored and the walls smoothed by a reaming process or the bore is finished by grinding.

Some cylinders have the valves placed so they open directly into the cylinder head, as shown at Fig. 41.

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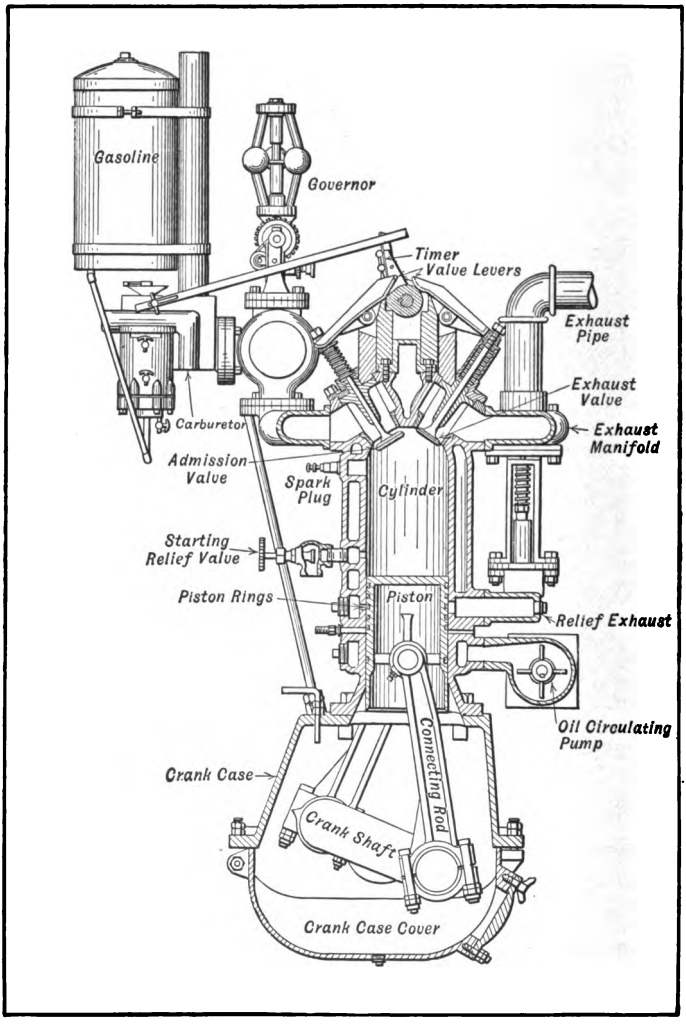

FIG. 41.—Sectional View of Valve in Head Vertical Motor Used on Hart-Parr Tractors, Cylinder and Head Integral.

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When this is done two methods of cylinder construction are possible. In the one that is more widely used the cylinder head is a separate casting, carrying the valves, and is bolted to the cylinder member as outlined at Figs. 42 and 43. The cylinder design depicted at Fig. 41 is a one-piece member having inserted valves, these members being mounted in removable cages.

Owing to the large size of tractor cylinders they are never cast in blocks of four as very often obtains in the latest automobiles. The individual cylinder casting has much in its favor, when made in large sizes. More uniform cooling is important because it insures that the change of form due to increase of temperature will be regular. This condition is more easily obtained when the individual cylinder is used than when block castings are employed. If one of the cylinders of a tractor power plant should become damaged it is much cheaper to replace the single large member than it would be to replace a cylinder block of two or four cylinders.

The method of construction outlined at Fig. 42 has the advantage that the cylinder head may be easily removed whenever it is desired to remove accumulations of carbon from the cylinder interior or when the valves, which seat directly into the cylinder head are to be ground. Direct gas passages are possible and the entering fresh gas, or the outgoing exhaust gas meets with little resistance, such as would be the case if the gas stream was forced to turn many corners. A typical cylinder head detached from the cylinder casting is shown at Fig. 43. It will be noticed that very large valves are used and that these seat directly into the cylinder head face. A tight joint is insured between the head and the cylinder casting by the use of a heat-resisting packing, which is compressed tightly between the two members by six sub-

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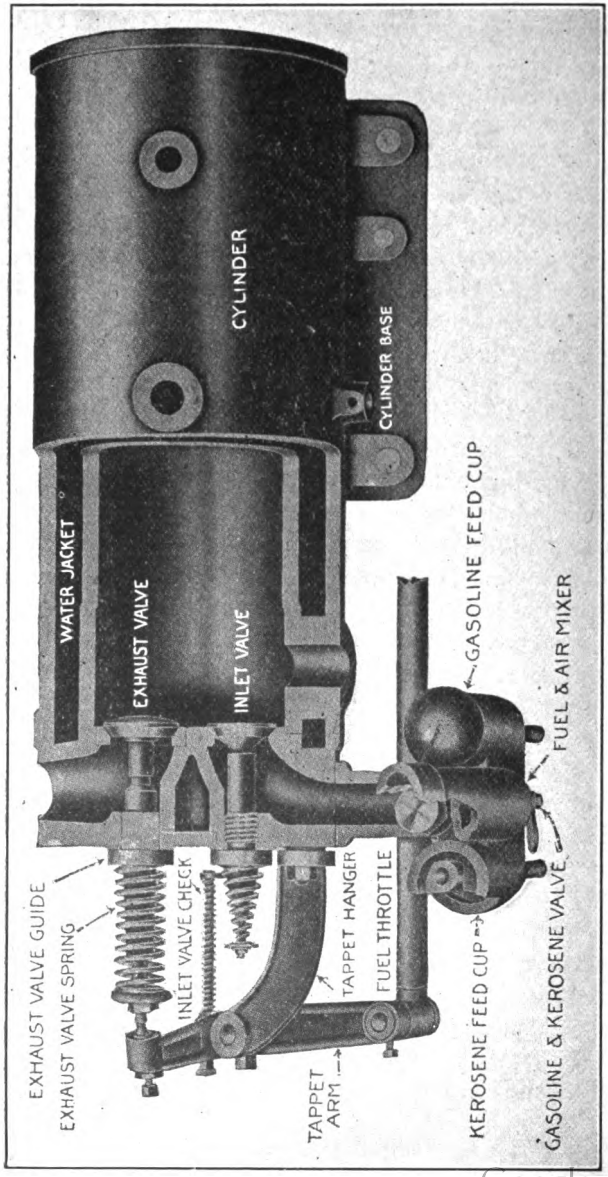

FIG. 42.—Valve-in-Head Cylinder Used on I. H. C. Horizontal Engine With Separable Head.

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stantial bolts. The rectangular spaces between the bolt holes are ports to permit free circulation of cooling water around the cylinder head.

Most tractor engines are of the long-stroke type, the ratio of the stroke to the bore being about one and one-half or two to one. A long-stroke motor will pull much better at low speed than a short-stroke type, and as most tractor engines are of the moderate speed form the

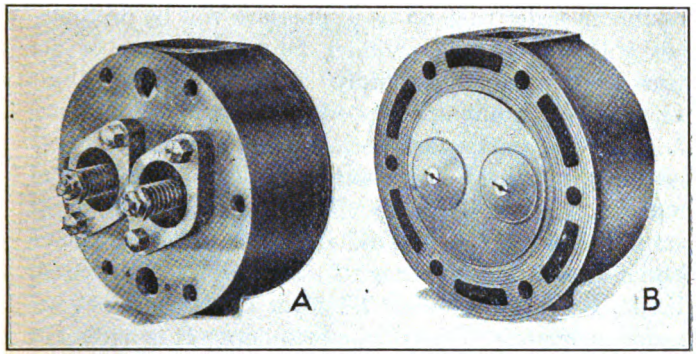

FIG. 43.—Exterior Face of Detachable Cylinder Head Shown at *A* Outlines Valve Retention by Cages. Interior Face Shown at *B* Indicates Large Valves Possible by This Construction.

stroke must be long in order to obtain an efficient piston speed.

Cylinders are usually fastened to the engine base by means of bolts passing through a substantial flange cast integral with the lower portion. This permits of ready removal when repairs are necessary without dismantling the entire engine. In some motors where the cylinder heads are detachable it is possible to remove the piston and connecting rod assembly through the open end of the cylinder without removing that member from the

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engine base. Sometimes when the separable head construction is employed the cylinder and part of the engine base are cast together, though this is not considered good practice except on small stationary power plants.

The Valve System.—The location of the valves and shape of the combustion chamber are factors that have a material bearing upon the power obtained from the gasoline motor. It is obvious that the gases must be admitted to and discharged from the cylinder as quickly as possible in order that no back pressure will be produced that will prevent the cylinder filling promptly or the burnt gases exhausting rapidly. Valve sizes also have a decided bearing upon the speed and power of the motor and some valve locations permit the use of larger members than do others without the penalty of using unsymetrical cylinder castings. There are many ways in which valves may be placed in the cylinder and each system has some advantages. The cylinder shown at Fig. 38 is known as the "T" form and the valves are carried at opposite sides of the cylinders. It is necessary to provide two cam shafts for valve operation with this method of construction and theoretically this is the worst form of combustion chamber as far as heat efficiency is concerned. The cylinder of the "L" type, such as shown at Fig. 39 is very widely used because both valves may be actuated from a common cam shaft. The combustion chamber form is more efficient than the "T" head construction, though it is possible to use larger valves, and manifolds with the latter, than with the "L" construction.

The method of valve application shown at Fig. 42 has many advantages. It is possible to waterjacket the valves thoroughly, which is somewhat difficult to do when the valves are mounted in cages. As the cooling

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water is in contact with the walls of the valve chambers, there is no loss of heat conductivity, as there would be at the joint of the inserted cage type. The valves may be large and as there are no pockets it is possible to have a combustion chamber of the most efficient form. The cylinder is easily cast and machined and as the interior face of the cylinder head may be finished smooth the combustion chamber has no projecting particles which may serve as anchoring points for carbon or which may cause preignition troubles by getting red hot.

The method of valve operation and placing has much to do with the size of the valve, and the review of the various methods of valve installation has shown that the largest size valves can be used in motors of valve-in-the-head type. If valves are of the automatic type, i. e., open by the suction of the piston, they should be about 20 per cent. larger in diameter than mechanically operated valves. The valve diameter should be equal to half of the cylinder bore if possible. The valves with the larger area do not have to lift as high as the smaller members and they are quieter in action besides impeding the gas flow less.

There are two common methods of valve construction, one in which the valve head is made of cast iron and the stem of machinery steel attached to the head by riveting, the other where the valve is machined from a one-piece forging of nickel or machinery steel. Bevel-seated valves are generally used in gasoline engines and most of these are provided with screw-driver slots on top of the head in order that they may be turned on their seat when grinding. Sometimes valves are made by electrically welding a nickel steel head to a carbon steel stem. This is considered a better method of construc-

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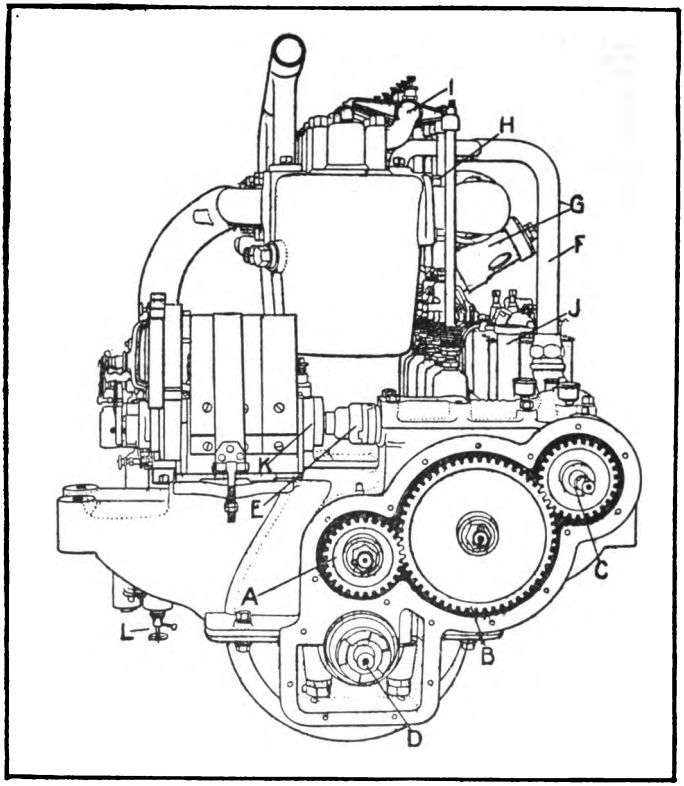

FIG. 44.—Front View of Power Plant With Timing Gear Case Cover Removed, Showing Conventional Method of Driving Cam Shaft.

tion than either of the two previously mentioned because there is no possibility of the valve heads becoming loose on the stem as is sometimes the case when a cast-iron head is riveted to a steel stem. It is preferable to the one-piece nickel steel construction because this material does not wear as well as does ordinary machinery steel. The factor of endurance is not slighted in order to use

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the metal that has a high degree of resistance to heat. The composite valve construction has the advantage that the head is made of a heat-resisting material, while the stem is made of steel that will not wear the valve-stem guide. As the head and stem are fused together by an electric current it is impossible to distinguish the joint and though made of different materials the valve is practically one piece.

Valves are operated by means of cams which may raise the valve from its seat through the medium of a simple plunger, as in the "T" and "L" head motors or by means of rocker arms and tappet rods used with valve-in-the-head motors. A cam is a small metal wheel having a raised projection at one point of the circle. This raises the valve plunger when it comes in contact with it. When the cam point is not in contact with the plunger there is a clearance between the plunger roller and the cam circle and the valve remains seated by virtue of spring pressure. Cam shafts may be driven from the crank shaft by any form of positive gearing. Sometimes they are driven by means of silent chains and sprocket, though the usual method of drive is by gears. A typical timing gear assembly is shown at Fig. 44. In this the pinion A is driven by a gear of the same size attached to the crank shaft. It meshes with the gear **B**, which is twice as great in diameter, which turns the cam shaft at half engine speed. The small gear **C** is used to drive the water-circulating pump and mechanical oiler. Timing gears of the better class tractor engines are encased in order to exclude dirt and grit and retain lubricant.

Piston and Rings.—The piston is a cast-iron reciprocating member that fits into the cylinder and which receives the impact of the exploding gas. It is one of the simplest elements of the tractor power plant and is

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one part that does not change much in form when used in different motor designs. It is a cylindrical member which has bosses in its interior to hold the wrist pin and grooves cut on the exterior wall in which cast iron packing rings are placed. Three forms of pistons are shown at Fig. 45. That at A is used in two-cycle motors and has a deflector plate or member cast integral with the head. That at B is the usual form used in the medium

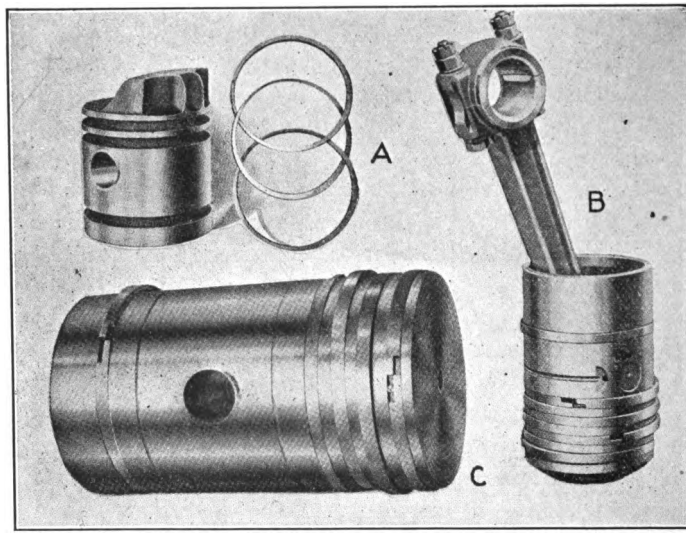

FIG. 45.—Types of Pistons Commonly Used. *A*—Piston With Deflector for Two Cycle Engine. *B*—Piston With Four Rings and Connecting Rod in Place, Used on Medium Duty Engines. *C*—Long Piston of Heavy Duty Engine.

duty engines and is shown with connecting rod in place. That at C is a long piston, such as used in a heavy-duty engine. A piston with rings removed is shown at Fig. 46.

As it is imperative that the pistons be free in the

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cylinders they are usually machined several thousandths of an inch smaller than the cylinder bore in order to leave sufficient clearance between the piston and cylinder walls for a film of oil and to allow for expansion due to heat. To make a gas-tight joint, packing rings are placed in the grooves of the piston. These have sufficient elasticity so that they bear tightly against the cylinder wall. As there is but a limited amount of ring surface in

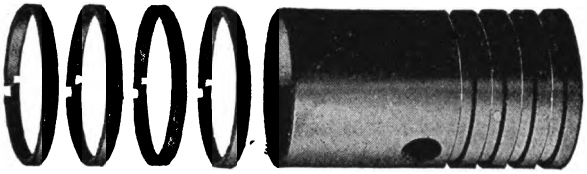

FIG. 46.—Piston With Packing Rings Removed.

contact with the cylinder and the split-piston rings are resilient so that they conform to irregularities in cylinder bore there is but little friction between properly fitted rings and the cylinder wall. The piston is free to move up and down in the cylinder and still a gas-tight joint is obtained by the use of the rings.

These packing members are made in two forms, the eccentric, in which one side of the ring is thinner than the other, and the concentric, in which the ring is a uniform thickness at all points. In some cases the piston-ring grooves are provided with pins to keep rings from turning around on the piston until all the slots are in line. The common form of joint is the lap or step joint, which is shown in the piston rings depicted at **B** and **C**, Fig. 45.

Connecting Rod Types.—The form of the connecting rod depends upon the type of engine in which it is used. As a general rule connecting rods are more

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than twice as long as the stroke of the piston. They are usually made of steel and either forged or formed from the slab. Sometimes they are made of high-tensile strength bronze castings. It is desirable to have softer metals in contact with the crank shaft than those of which the connecting rods are composed so bushings of phosphor bronze or babbit metal are employed at the ends that

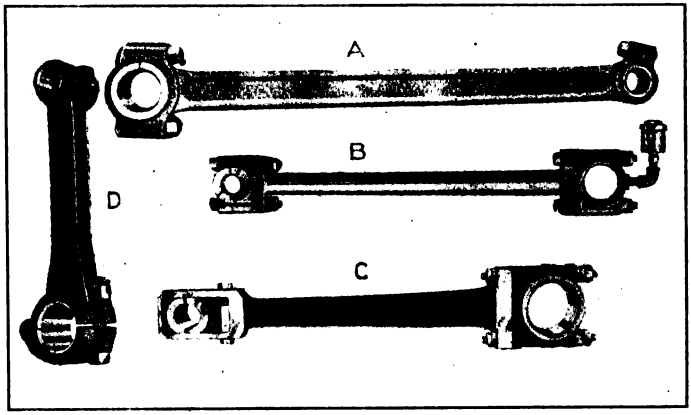

FIG. 47.—Types of Connecting Rods Used in Tractor Engines. *A*—Simple Marine Type Used in Long Stroke Motor. *B*—Built-up Marine Type With Adjustable Wrist Pin Box. *C*—Marine Type With Wrist Pin Bushing Adjustment By Wedge. *D*—Simple Hinged Lower Cap Type Used in Vertical Cylinder Short Stroke Motor.

are to receive the crank pin and wrist pin. Bronze is commonly used at the upper end on account of the heat this bearing is subjected to, while the white metal is used at the lower or crank-pin end.

The upper end of the connecting rod may be one piece because the wrist pin can be introduced after connecting rod is in place between the bosses of the piston.

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Owing to the irregular shape of the crank shaft it is necessary to make the lower end of the connecting rod in two pieces. Various designs of connecting rods are shown at Fig. 47. That at **A** is a simple drop-forged type used in long-stroke engines, the connecting rod and the upper half of the crank-pin bearing are formed integral while the lower cap is the separable member held in place by bolts. The upper end is provided with a split lug which is clamped together by a bolt to hold the wrist-pin bushing in place. The form outlined at **B** is a marine-type rod composed of a central portion of steel having "T" pieces formed integral at each end. Both wrist-pin bushing and crank-pin bearing are made in two pieces of bronze and are fastened to the flange ends by means of steel-securing bolts.

The connecting rod shown at **C** is somewhat similar in design except that it is rectangular in section instead of round. This is also a marine-type connecting rod having bronze boxes at the upper and lower end. The wrist-pin boxes are carried in the upper end of the connecting rod which forms a box around them in such a way that they may be tightened to compensate for wear by means of a wedge and adjusting bolt. The member outlined at **D** is a modified marine form in which the lower bearing cap is a hinged member retained by one bolt instead of two as in the other construction. This form of connecting rod is generally used on medium-duty engines, while the other three types are used on heavy-duty power plants. The various structural shapes in which the main portion of the rod can be formed are also clearly shown at Fig. 47. That at **A** is an I-beam section. At **B** the section is circular. The connecting rod at **C** has an approximately rectangular cross section, while that at **D** is an **H** section rod.

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Bearing adjustment is obtained in all cases by removing shims from between the halves of the boxes and screwing them closer together by means of through bolts. A number of liners are used, these being thin brass or copper stock several thousandths of an inch thick. As the brasses wear, shims may be removed and the boxes brought closer together to take up any lost motion that exists.

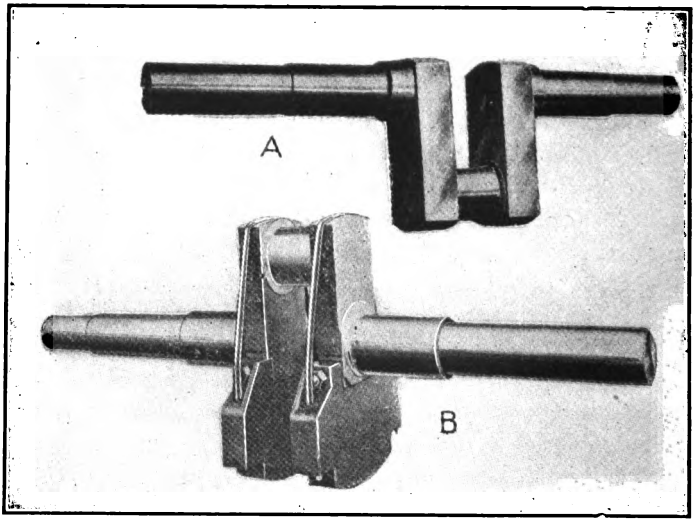

FIG. 48.—Types of Single Cylinder Crankshafts. *A*—One Throw Shaft Without Balance Weights. *B*—Crankshaft With Counterbalance to Reduce Vibration.

Crank-shaft Forms.—As practically the entire duty of transmitting the power developed by the motor devolves upon the crank shaft these must be made of the highest quality steel and possess exceptional strength. They are usually made of drop or machine forgings,

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though sometimes they are blocked out of a solid slab of metal. The form of the shaft depends upon the number of cylinders. Those shown at Fig. 48 are for single-cylinder motors as they have but a single crank throw. That at A is a simple form used in motors where the counterbalance weights are attached to the fly-wheels, while that at B has the weights (which are intended to balance the reciprocating parts) attached to the crank webs.

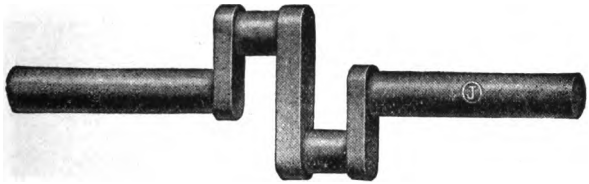

FIG. 49.—Forging For Two Throw Crankshaft.

The forging of a two-cylinder crank shaft is shown at Fig. 49. It will be seen that in this member the cranks are spaced on the halves of the circle or 180 degrees apart. Crank shafts used with single-cylinder motors consist of two webs, one crank pin and the crank shafts proper. These are practically always formed in one piece on tractor motors, though built-up crank shafts in which these pieces are separate and fastened together are sometimes used in light motors, such as employed for motor-cycle propulsion.

A crank shaft such as would be used on the ordinary form of opposed motor is shown at Fig. 50-A in its finished condition. The bearings are exceptionally long and keyways are machined in the shaft to receive the keys for fly-wheel retention. Four-cylinder crank shafts as used in tractor engines usually have three or five main bearings. The three-bearing crank shafts are used on those engines where the cylinders are cast in pairs, while

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the five-bearing shafts as depicted in Fig. 50-B are used on motors having individual cylinder castings. On medium and heavy-duty power plants, the five-bearing crank shaft is considered better because it is supported by a bearing at the sides of each crank throw. The crank shaft shown has a flange forged integral at one end to which the fly-wheel is attached by bolts.

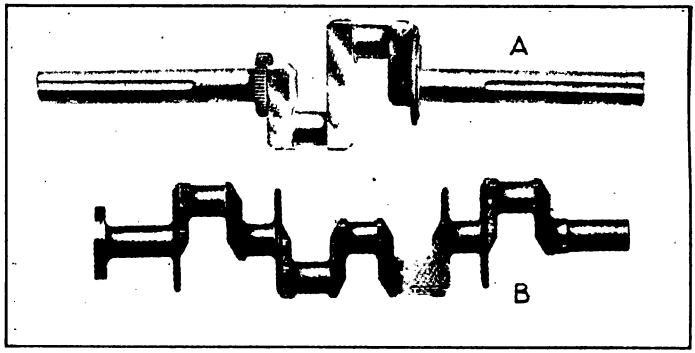

FIG. 50.—Crankshafts for Multi-cylinder Motors. *A*—Two Throw Crankshaft With Timing Gear Attached. *B*—Four Throw, Five Bearing Shaft.

Utility of Fly-wheel.—The gasoline engine of the one or two-cylinder type would not be a practical power producer without some means of equalizing the uneven power generation. Energy must be stored up to carry the crank shaft and other moving parts through the idle strokes and this is usually accomplished by providing a heavy wheel which will continue to revolve after an initial impulse given it no longer exists. A fly-wheel is usually a heavy cast-iron member, having the rim, spokes and hub cast integral. The larger diameter fly-wheels do not need as heavy rims as do those where the weight is carried nearer the center of the shaft. The fly-

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wheel weight depends upon the number of cylinders and power of the motor. Assuming conditions where motors would have the same power, those having the least number of cylinders would require the heaviest fly-wheel.

As a general rule about ninety to one hundred pounds fly-wheel weight is allowed to each horse-power of moderate speed one and two-cylinder engines. As the number of cylinders increases, the number of explosions and the torque become more uniform and the fly-wheel weight can be reduced. If a single-cylinder engine of a certain power required a fly-wheel of four hundred pounds weight, a double-cylinder engine would operate satisfactorily with one weighing three hundred and twenty pounds and a four-cylinder motor would require but two hundred pounds of fly-wheel weight. Some of the important conditions that determine fly-wheel dimensions are bore of the cylinder, compression in pounds per square inch, speed of crank-shaft rotation, and method of power transmission.

Usually multiple-cylinder engines of large bore have fly-wheels heavier than are actually needed in order that the engine may be more easily started. Heavy-duty engines require heavier fly-wheels than medium-duty types and engines which must run steadily, such as those furnishing power to drive a dynamo for electric lighting, require heavier fly-wheels than do motors intended merely for traction purposes. Fly-wheels used on tractor engines are generally simple-spoked forms when made for single-cylinder engines though the forms used for multiple-cylinder motors often dispense with spokes and have a solid web of metal joining the fly-wheel rim and hub.

It is important that the fly-wheel be held to the shaft in a positive manner. The simplest method consists of

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boring out the fly-wheel hub so it is a tight fit on the crank shaft and then driving in a key between the shaft and hub into suitable keyways machined in these members to prevent the fly-wheel from turning. A better method of fly-wheel retention is outlined at Fig. 51. In this a flange is formed integral with the crank shaft and the fly-wheel member is firmly secured to this by means of substantial retaining bolts. When these are properly fitted it is practically impossible for the fly-wheel to become loose, as sometimes happens in the simple-keyed construction.

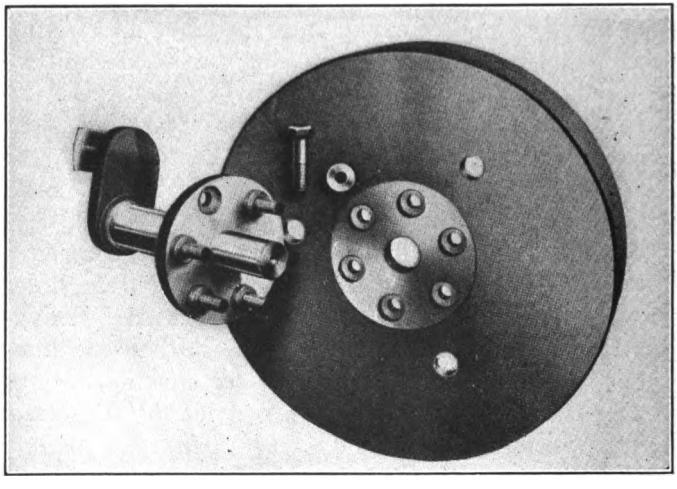

FIG. 51.—Typical Fly-Wheel and Method of Attaching to Crankshaft Flange by Bolts.

The diameter of a fly-wheel must be held to certain limits and the weight one can put at the rim is restricted by the limits imposed on circumferential speed. It is stated that a safe speed for a cast-iron pulley is about a mile a minute for any point on its circumference. The

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slower the speed of the engine, the larger the diameter of the fly-wheel one can use and the more effective it becomes as a balancing member. A fly-wheel 3 feet in diameter would have a circumference of approximately 10 feet. As any point on the rim would turn this distance in a revolution, in order not to exceed the safe peripheral speed the fly-wheel should not revolve faster than 500 revolutions per minute. If a fly-wheel was 6 feet in diameter its circumference would be twice as great as the small member previously mentioned and its speed would be limited to 250 revolutions per minute.

Engine Base and Bearings.—All gasoline engines require a substantial base member to which the cylinder or cylinders are attached and which supports the crank shaft as well. The engine base must be of substantial construction in order to keep all parts of the motor in alinement and will vary widely in form depending upon the type of engine. Engine bases used on the simpler tractor power plants are made of cast iron, though some of the engine bases used with the multiple-cylinder engines of the automobile type are made of aluminum. Cast iron is a suitable material for this purpose, and while it is somewhat brittle and unreliable in nature when made in light sections, there is not the need for saving weight in a tractor engine that exists in automobile practice, so strength is obtained by using a little more iron.

A simple engine bed such as used for a single-cylinder stationary type power plant is shown at Fig. 52, and it will be noticed that the lower portion of the crank-shaft bearings are formed integral with the engine bed. On the multiple-cylinder engines the form of the crank case will depend upon the number of cylinders and their dis-

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position. They are often approximately cylindrical members, which may be divided horizontally along the crank-shaft center line or which may be in one piece, having end plates to support the main bearings and large openings through which the interior mechanism can be inspected. It is obvious that the diameter of the crank case must be large enough to permit the crank shaft and connecting rod big ends to turn inside of it, and its length is controlled by the number of cylinders and their arrangement.

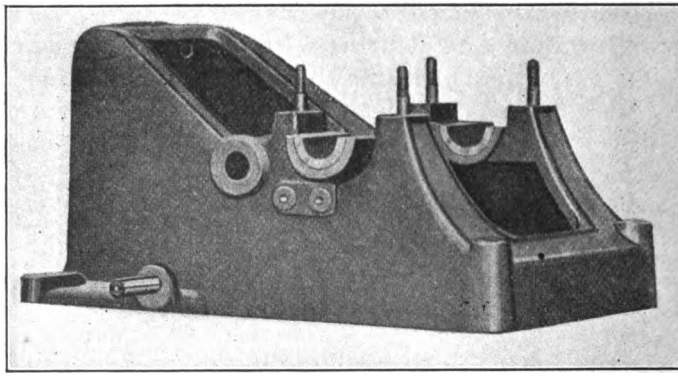

FIG. 52.—Base for Single Cylinder Heavy Duty Motor.

The crank case of a single-cylinder or double-opposed cylinder, horizontal type, would be about the same in length. That of a four-cylinder engine will depend upon the method of casting the cylinders. A shorter crank case is utilized when the cylinders are cast in pairs than when individual cylinder castings are employed. The crank case shown at Fig. 53 is a type used on a three-cylinder engine and is somewhat shorter than would be necessary with four cylinders. As will be evident, it consists of two parts. The upper portion serves as the

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engine-bed proper and carries the cylinders and crank shaft. The arms by which the engine is supported on the tractor frame are cast integrally with the upper member. The lower portion of the crank case serves merely as an oil container and cover for the working parts and may be easily removed to permit thorough repairing of the interior mechanism.

A superficial examination of the parts is made possible

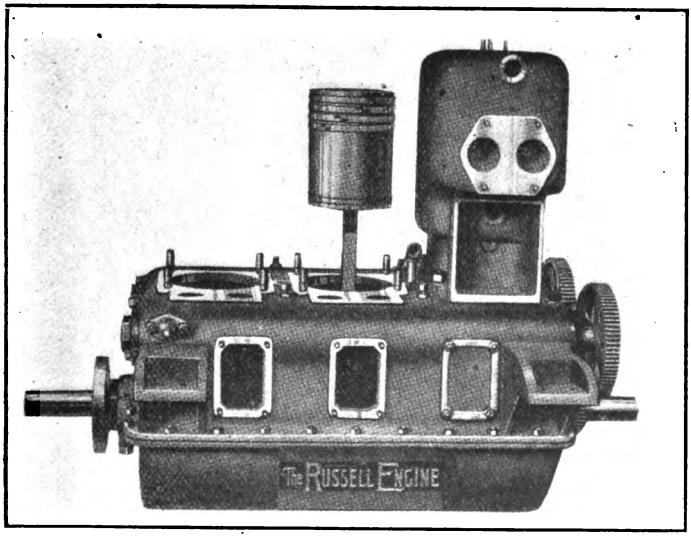

FIG. 53.—Crankcase of Russell Three Cylinder Tractor Motor Composed of Two Halves and is Split Longitudinally at Crankshaft Center Line.

by means of readily removable plates at the side of the crank case, though when repairs of a serious nature are made, such as adjusting the connecting rods or main bearings, it is best to remove the lower half of the engine base. A four-cylinder crank case of the barrel type is

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shown at Fig. 54. As will be seen this construction calls for the use of end-bearing plates, which carry the front and rear main journals, while the three main bearings inside the crank case are attached to the partitions which separate the lower portion into four compartments. The cylinders are held in place by a series of stud bolts screwed into the top of the case. In order to gain access

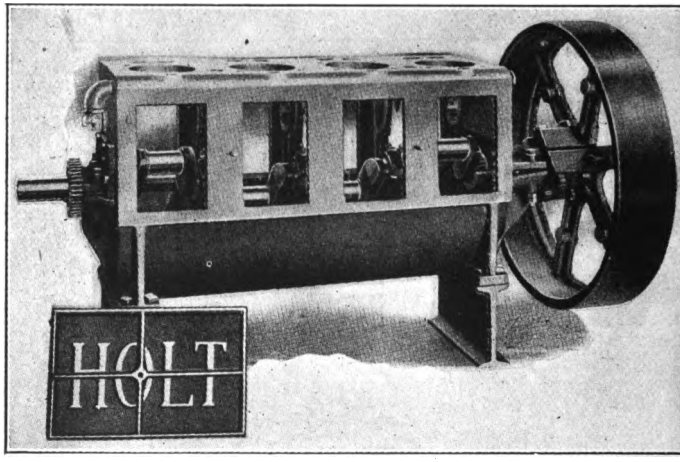

FIG. 54.—Crankcase of Holt Tractor Engine, a One Piece Casting With Removable Side Inspection Plates.

to the interior large openings are provided at both sides of the crank case and are closed by substantial cover plates, such as shown leaning against the engine base when the assembly is completed. The main object in engine-base design is to have the member a substantial one that will keep the crank shaft rigidly in line with the connecting rods and pistons and which will be of such design that the various parts will be accessible for inspection or adjustment without having to dismantle the entire power plant.

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CHAPTER V.

MAKING AND EXPLODING THE GAS.

The Liquid Fuels—Gasoline—Kerosene—Alcohol—Elements of Carburetion—Simple Mixing Valves—Float Feed Carburetor Action—Automatic Carburetors—Parts of Carburetors—Typical Gasoline Carburetors—Carburetor for Two-cycle Engines—Action of Kerosene Vaporizer—Methods of Exploding Charge—Advantages of Electric Ignition—Methods of Producing Current—Dry and Storage Batteries—Function of Induction Coil—Producing Spark in Cylinders—Mechanical Generator Advantages—Types of Magnetos—Oscillating Armature Forms—Types with Revolving Armature—True High Tension Device—Low Tension Ignition System—Simple Battery Ignition Methods—Action of Magneto Ignition System—Timing the Spark.

The Liquid Fuels.—The great advance of the internal combustion motor can be attributed more to the discovery of suitable liquid fuels than to any other factor. The first gas engines made utilized ordinary illuminating gas as a fuel, and while this is practical for use with stationary power plants wherever it is available, such as the natural gas fields of the Middle West, or in cities and towns having a central gas producing plant, it is obvious that it could not be very well applied to portable self-propelling power plants used for tractor propulsion. When it was discovered that certain of the liquid fuels belonging to the hydrocarbon class, which includes petroleum and its distillates, benzol and benzene, which are coal tar products, and alcohol, were suitable, the gas engine became widely used as a prime mover.

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The liquid fuels have the important advantage that a quantity sufficient for an extended period of engine operation can be easily carried in a container that will not tax the capacity of the engine and that requires but comparatively little space in any out-of-the-way portion of the frame. When used in connection with a simple vaporizing device, which mixes the liquid with sufficient quantities of air to form an inflammable gas, the fuel is automatically supplied to the engine without any attention being demanded from the operator as long as the supply in the tank is sufficient to produce a flow of liquid through the pipe joining the mixing device and fuel container.

Gasoline.—Up-to-date the most important fuel used in connection with gas engines has been one of the distillates of crude petroleum, known generally to the trade as "gasoline." This liquid, which is a clear white very light bodied substance, evaporates very rapidly at ordinary temperatures. This feature made it especially adaptable for use with the early forms of mixing valves because it mixed so readily with air to form an explosive gas. Fifteen years ago there were very few industrial uses for gasoline and it sold for less than five cents a gallon in some cases. During the past decade the demand for it has increased by leaps and bounds, and it now sells for four times as much as it did when the gasoline engine was first introduced.

The specific gravity of gasoline varies from sixty to seventy-six degrees, though very little of the latter is now obtainable except by special arrangement with the oil producing company. It was formerly thought that gasoline any heavier than seventy-six degrees would not work satisfactorily in the cylinders of the gas engine, and while this is true of the early crude and

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inefficient vaporizers, modern mixing devices have been evolved which handle gasoline of sixty-two degrees specific gravity and even heavier. The percentage of gasoline produced from crude oil in proportion to the other elements is very small, and as the demand has increased to such proportions, the tendency of the producer has been to make gasoline heavier or of lower

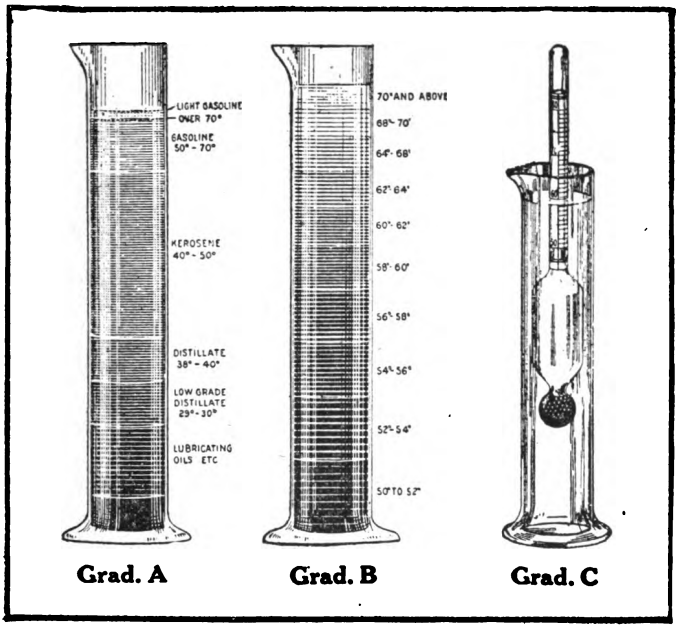

FIG. 55.—Graduate *A* Shows Proportion of Different Products Obtained From Kansas Crude Oil. The Fractional Distillation of Gasoline is Shown in Graduate *B*. Method of Making Baumé Test Shown at *C*.

specific gravity by distilling off some of the heavier oils with it to increase the bulk produced.

If one refers to graduate A shown at Fig. 55, the proportion of gasoline obtained by distillation from

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crude petroleum may be easily learned. The term "gasoline" is now applied to all products testing over fifty deg. Baumé. Less than six per cent of the bulk of the petroleum base becomes light gasoline of over sixty-four degrees. The larger bulk of the petroleum is refined into kerosene which tests from forty to fifty deg. Baumé. The crude petroleum is broken up into three main groups of products, as follows: Highly volatile, gasoline, benzine, and naphtha, eight to ten per cent; light oil, such as kerosene and light lubricating oil, seventy to eighty per cent; heavy oils or residuum, five to nine per cent. In order to make clear the enormous consumption of gasoline in this country, experts have estimated that if all the internal combustion engines in use which depended on this fuel were to be operated continuously for a day of ten hours, over seven million five hundred thousand gallons of liquid would be consumed.

Kerosene.—In order to understand thoroughly the action of fuels in an internal combustion engine and their value, one should understand to some extent the process of distillation to which the crude oil is subjected. The petroleum is pumped into a large steel boiler or still, from which a pipe leads to a condenser. The liquid is gradually heated, and as the gas rising from the crude oil escapes through the condenser, it is cooled at this point and again becomes a liquid. The liquid flowing from the condenser is constantly tested with a Baumé tester, and as the specific gravity of the distillate changes to the different weights, the liquids are run off into separate storage tanks.

The lighter liquids testing about eighty deg. Baumé come off first, and as the crude oil becomes hotter the heavier constituents are volatilized and the substance

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coming from the condenser gradually becomes heavier. The process continues till nothing is left of the crude oil but a species of solid matter resembling coke which is composed of carbon and the various earthy matters that were contained in the crude product. The refineries obtain gasoline varying in quality from eighty degrees down to fifty degrees, kerosene from fifty degrees down to forty degrees, distillate from forty degrees down to twenty-nine degrees, and below that lubricating oils. The various proportions are clearly shown in graduate A at Fig. 55.

Kerosene, as sold to-day, varies between forty-two deg. and forty-five deg. Baumé. Heretofore it has been the common belief that because gasoline is more easily evaporated and exploded than kerosene, it gives more power, but actually the properly vaporized kerosene contains more heat units than gasoline and this applies just as well to the lower grades of oil which are sold under various names, such as distillate, solar oil, fuel oil, etc. The graduate at B, Fig. 55, shows the various proportions in which gasoline may be divided. As will be evident it consists of quite a number of liquids having different specific gravities. These are mixed together and the resulting gasoline has a specific gravity that is an average of the various grades mixed together to form the product.

The liquid known as kerosene is not composed of such a widely varying number of constituents as is gasoline and it remains more constant in quality. The difficulty which has obtained and which has militated against the general use of kerosene has been the difficulty met with in vaporizing it at ordinary temperatures. It is practically impossible to start an electrically ignited engine on kerosene when cold. The metal parts

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of the combustion chamber and vaporizer must first be raised in temperature before kerosene can be used successfully. The grades of gasoline now sold for fuel will evaporate in winter without much difficulty, but kerosene will not give off vapors unless heated to nearly the boiling point of water.

Where kerosene is used for fuel it is customary to provide an auxiliary gasoline supply which may be used to operate the engine until it has become hot enough to run on the heavier fuel. As so large a proportion of the crude oil yield is distilled into kerosene its price is considerably lower than that of gasoline and many of the modern gas tractors are provided with mixing devices that will use gasoline to start the engine on and then kerosene or distillate after the power plant becomes heated.

The method of making a Baumé test is outlined at Fig. 55-C. The tester is a species of hydrometer. This consists of a glass tube having an enlarged lower portion filled with air in order that it may float in a liquid and a small ball filled with shot at the lower end to keep the device vertical in the liquid in which it is floated. The stem of the hydrometer is provided with a scale, calibrated to read in degrees, and the specific gravity of the liquid is clearly indicated and its nature may be easily determined by this test. The stem will sink lower in the lighter liquids, so the figures denoting the liquids of higher specific gravity are nearer the top.

Alcohol.—Gasoline and kerosene are derived from natural mineral deposits which will become more and more depleted as the demand for the product becomes greater. Petroleum was formed ages ago, presumably from decaying vegetation, and like coal the supply is not inexhaustible. While there is no immediate fear

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of a petroleum famine, considerable experimenting is being carried on by engineers to attempt to use alcohol as a substitute for the hydrocarbons commonly used at present.

Alcohol is the one fuel that can be produced in quantities that could be increased as the demands for it augmented. It is produced by distilling various vegetable substances, and as these are reproduced each cycle of seasons, the raw material from which alcohol may be manufactured, in addition to being found in all parts of the world, would be renewed periodically. Alcohol differs materially from gasoline in that it is less volatile and requires more heat to vaporize it. It cannot be used successfully in engines designed for gasoline or kerosene as higher degrees of compression than are practical with either of these commonly used fuels must be provided in order to burn alcohol efficiently.

Experiments have been made with a view of permitting one to use alcohol in engines of present design by passing alcohol vapor through calcium carbide before it enters the cylinder. As alcohol contains water, this substance liberates acetylene gas when it comes in contact with the carbide and the resulting alcohol-acetylene gas can be burned in engines of conventional design and satisfactory results obtained.

The fire risk with alcohol is much less than with either gasoline or kerosene, as while water only serves to spread burning petroleum products, it will extinguish an alcohol fire. Some authorities contend that alcohol will be the fuel of the future, but in this work the writer intends to deal only with practical matters of to-day so that but brief mention of the character and possibilities of alcohol as fuel is considered necessary.

Elements of Carburetion.—Carburetion is a pro-

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cess of combining the volatile vapors evaporating from the hydrocarbons previously mentioned with enough air to form an inflammable gas. The amount of air needed varies with the character of the liquid fuel and some mixtures burn much quicker than others. If the fuel and air mixture is not properly proportioned the rate of burning will vary and either an excess of fuel or air will reduce the power obtained from combustion materially. The proportions of air and liquid needed vary according to the chemical composition of the liquid.

Gasoline, which is that commonly used at the present time, is said to comprise 84 per cent carbon and 16 per cent hydrogen. Oxygen and nitrogen form the main elements of the air and the former has a great attraction for the main constituents of hydrocarbon liquids. What we call an explosion is merely an indication that the oxygen of the air has combined with the carbon and hydrogen of gasoline. In figuring the proper amount of air to mix with a given quantity of fuel one takes into account the fact that eight pounds of oxygen are required to burn one pound of hydrogen and that two and one-third pounds of oxygen are necessary to insure the combustion of one pound of carbon. As air is composed of one part of oxygen and three and one-half portions of nitrogen by weight, for each pound of oxygen one needs to burn either hydrogen or carbon, four and one-half pounds of air must be allowed. About sixteen pounds of air must be furnished to insure combustion of one pound of gasoline, the hydrogen constituent requiring six pounds of air while the carbon component needs ten pounds of air.

Air is not usually considered as having much weight, but at a temperature of 62 deg. Fahr. fourteen cubic

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feet of air will weigh a pound. Two hundred cubic feet of air will be needed to burn a pound of gasoline according to theoretical considerations. The element nitrogen, which is the main constituent of air, is a deterrent to burning as it does not aid combustion or burn itself. Therefore, it is usual practice to provide four hundred cubic feet of air to each pound of gasoline. Mixtures varying from one part of gasoline vapor to from four to thirteen parts of air can be ignited, but the best results are obtained when five to seven parts of air are combined with one of gasoline vapor. This mixture produces the most rapid combustion, the highest temperature and, consequently, the most pressure.

Simple Mixing Valve.—All devices that will mix gasoline vapor and air in proper proportions so the mixture will burn are called vaporizers. This general class may be divided into two distinct types of carburetor. The simplest of these is termed a mixing valve and its principle of operation is very easily understood. A sectional view of a typical simple mixer is shown at Fig. 56. It consists of a cast bronze body in the shape of an elbow having a valve seat machined about half way in its interior. A mushroom valve seats against the brass body and separates the device into two parts, as the valve head is held normally in contact with the valve seat by means of a light coil spring. The fuel supply is led to a small branch member attached to one side of the main body of the mixing valve and having a small passage that communicates with one of the walls of the valve seating member. The area of this passage is regulated by a needle valve which may be turned conveniently by a large knurled head. The passage is normally kept closed by the head of the mushroom valve. The device is attached to the

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engine at the connection marked "Mixture outlet" and the other end has free access to the air.

When the piston draws in a charge of air on its intake stroke it will open the air valve which at the same time uncovers the gasoline spray passage and a stream of gasoline mixes with the incoming air current and is

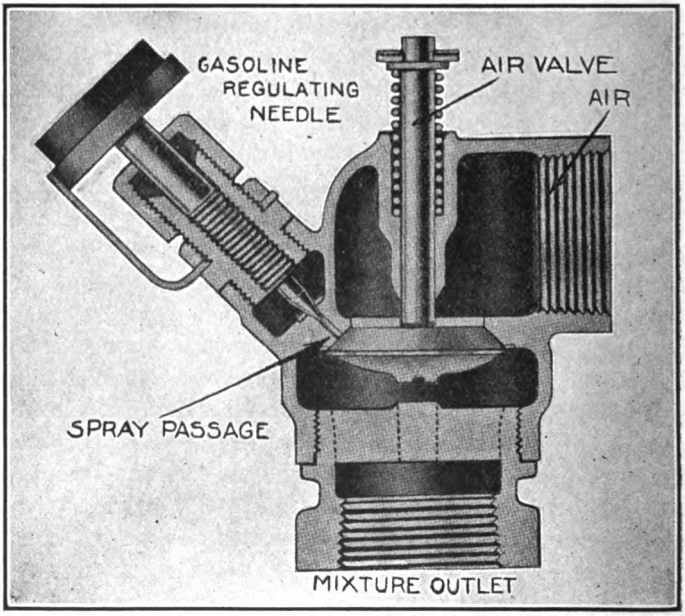

FIG. 56.—Sectional View of Simple Vaporizer Valve.

vaporized when it reaches the interior of the cylinder. As soon as the inlet valve of the motor closes, the small air valve of the mixing device is returned to its seat by the coil spring and both air and gasoline passages are shut off simultaneously. The mixture proportions may be regulated by varying the amount of gasoline

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supplied, which is done by altering the area of the spray passage with the needle point of the gasoline regulating valve.

Another simple mixing valve which combines a suction gasoline feed from a tank placed lower than the intake valve is outlined at Fig. 57. In the device shown at Fig. 56 it is necessary to place the gasoline tank

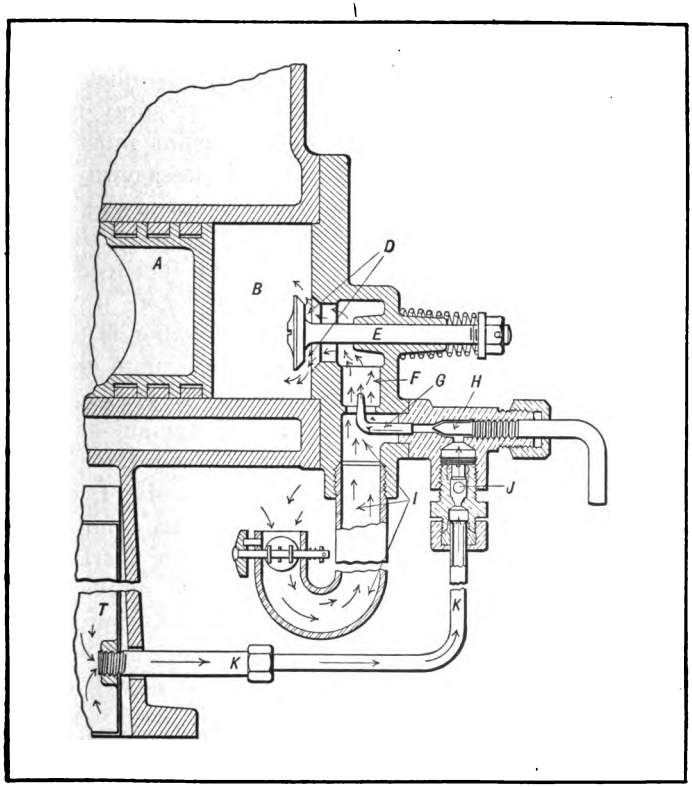

FIG. 57.—Sectional View Explaining Action of Gray Fuel Vaporizer.

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higher than the vaporizer body and depend upon a gravity feed. This means that the gasoline supply must be shut off every time the engine is stopped, in order to prevent flooding. When a suction feed is used, the gasoline supplied the vaporizer stops flowing automatically when the engine stops. When the piston **A** moves forward a partial vacuum in the firing chamber **B** is created. This causes the inlet valve **E** to lift from its seat **D** and air rushes into the combustion chamber through the supply pipe **I** and then past the inlet valve **E**. The air pipe is restricted around the spray nozzle **G** so that the air rushing past this point must flow faster on account of the constricted passageway and considerable suction is present at the point of the spray nozzle. Thus when the needle valve **H** is opened slightly gasoline from the tank **T** passes up the fuel feed pipe **K** and is sprayed into the chamber **F** where it mixes with the air current and the resulting vapor is drawn into the combustion chamber **B** by the vacuum created by the piston. A check valve is placed in the gasoline pipe at **J** so the level of gasoline will remain at that point while the engine is running. When the piston reaches the end of its suction stroke the valve **E** closes and the gases in the compression chamber are compacted and fired at the proper point by an electric spark.

Float Feed Carburetor Action.—The simple mixing valve forms have disadvantages of some moment, the main defect being that they are somewhat erratic in action and that the mixture cannot be as well regulated as when float feed carburetors are used. While the primitive forms gave fairly good results with high grade gasoline they do not carburate the lower grades of fuel used to-day properly and do not supply enough gas of proper consistency for the present types of engines.

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The most efficient modern power plants utilize float feed carburetors instead of simple mixing valves. The advantage of the float construction is that the gasoline is maintained at a constant level regardless of engine speed. In the simple forms of generator valves in which the gasoline opening is controlled by a poppet valve a leak in either valve or valve seat will allow the fuel to flow continuously whether the engine is drawing in a charge or not. During the idle strokes of the piston when there is no suction effect exerted to draw in gasoline vapor, the liquid fuel will collect around the air opening, and when the engine does draw in a charge it is excessively rich because it is saturated with globules of liquid fuel.

With a float feed construction a constant level of gasoline or other fuel is maintained at the right height in the stand pipe, and will only be drawn out of the jet by the suction effect of the entering air stream. The objection to the simple mixing valves utilizing suction feed is that the tendency is to draw off only the more volatile constituents of the fuel and that after a time the heavier elements comprising gasoline will remain in the container and will not be properly vaporized. Obviously the engine is not capable of utilizing all of the fuel. With a float controlled spray nozzle the spray is composed of all the constituents of the liquid and the lower grade portions that are mixed with those having higher evaporation points are drawn into the cylinder and burnt instead of settling to the bottom of the tank.

The simplest form of float feed carburetor is shown at Fig. 58. In this the principle of mixing the gasoline vapor and air is the same as in the simpler mixing devices but the method of fuel supply is different.

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The device consists of two parts, a float chamber and a mixing chamber. The standpipe in the mixing chamber is connected to the float chamber and the arrangement is such that the level of liquid in the float chamber is kept to a height equal to that of the spray nozzle. The method by which this may be accomplished is clearly shown at Fig. 58. The fuel pipe from the tank or main container is coupled to the top of the float chamber and the opening is closed

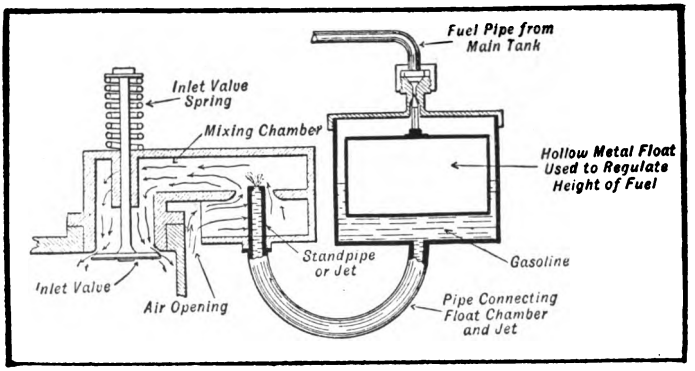

FIG. 58.—Diagram Showing Action of Float Feed Carburetor Evolved by Maybach.

by means of a needle point carried by a hollow metal float. The length of the needle is such that its point shuts off the gasoline supply when the level of gasoline in the float chamber coincides with the top of the standpipe. Whenever the fuel is drawn out of the float chamber sufficiently fast so the level is reduced, the hollow float will sink with the decreasing liquid and the passage in the fuel supply pipe is opened, allowing gasoline to flow into the float chamber until the liquid is at the proper height. Just as soon as the proper level is reached

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the float and the needle it carries are raised until they shut off the flow of gasoline from the tank.

Automatic Carburetors.—The simple form of float feed spraying carburetor has disadvantages that made improvements in construction necessary before it became really efficient. One of these was that as the engine speed increased the suction effect augmented in proportion, and as more gasoline was sprayed into the mixture because of the higher degree of vacuum created

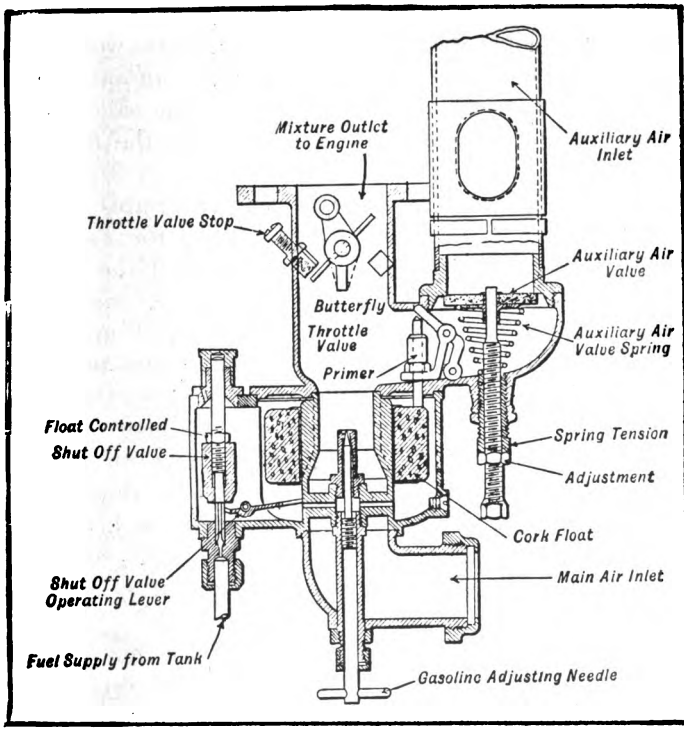

FIG. 59.—Sectional View of Modern Concentric Float Automatic Carburetor.

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in the cylinder, the mixture became too rich at high speed. This is the main reason for the introduction of the modern automatic carburetor, such as shown at Fig. 59. In this device the needle valve is mounted concentric with the float, i. e., the mixing chamber passes through the center of the carburetor, while the bowl, in which a circular float is placed, surrounds the mixing chamber. The air pipe is constricted around the spray nozzle in order to get the proper air speed to insure positive suction of liquid at low engine speeds. At high engine speeds, when the mixture would be too rich in the simple form of carburetor, an automatic auxiliary air valve, which is carried to one side of the mixing chamber, opens and admits air to the mixture to dilute it.

The concentric float chamber feature insures a constant level of fuel at the nozzle. When the nozzle is carried at one side of the float chamber, if the carburetor tilts, as is possible when a tractor is running on rough ground, or climbing or descending a grade, if the float chamber is higher than the nozzle the carburetor will flood. If conditions are reversed the level of fuel in the spray nozzle will not be high enough, and the mixture will be too thin. With the spray nozzle placed at the central point of the device, no reasonable amount of tilting will change the height of the liquid at that point and a mixture of constant proportions is insured under all abnormal as well as normal operating conditions.

Parts of Carburetors.—Outside of the main body of the device, the important parts of the carburetor are the spray nozzle or jet, the float mechanism, and the auxiliary air valve. Three types of spray nozzle are shown at Fig. 60. That at A is the simplest form,

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and the amount of fuel supplied the mixture is determined by the size of the opening through which the gasoline issues. With this form of nozzle it is not possible to regulate the gasoline supply and all mixture changes must be made by altering the amount of air admitted. With the spray nozzle shown at **B** and **C** very close regulation is possible because the spray opening is controlled by a needle pointed valve. At **B** the valve is at the top of the spray nozzle, while at

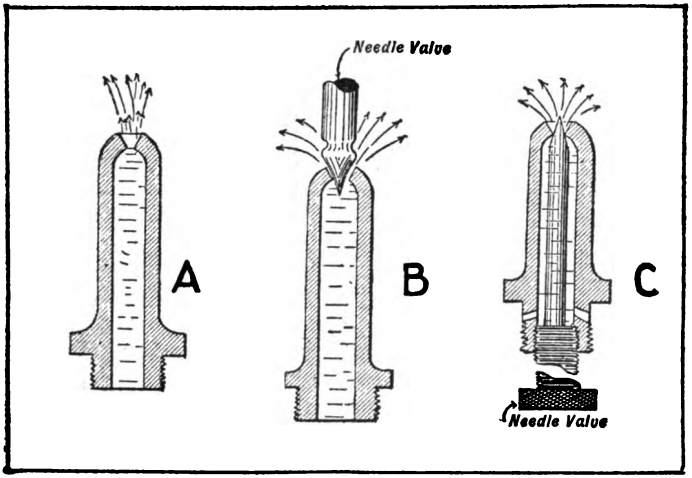

FIG. 60.—Showing Forms of Spraying Nozzles Used in Gasoline Carburetors.

C it comes up through the spray nozzle interior. Some authorities contend that the method outlined at **B** is superior because the needle point tends to break up the spray more than when the needle valve comes up from the bottom. With the type of nozzle shown at **A** the fuel issues in a solid stream instead of a spray and the mixture is not so intimate as when the issuing gasoline is broken up into a mist by the needle points. The

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amount of gasoline supplied the mixture may be regulated with minute exactness with either form of needle valve, and practically all of the modern successful carburetors of American design employ this system of fuel regulation.

Float chambers vary widely in form from very simple types to others using more or less complicated balancing systems of needle valve control. Two simple forms of float chamber which are sufficient to explain the prin-

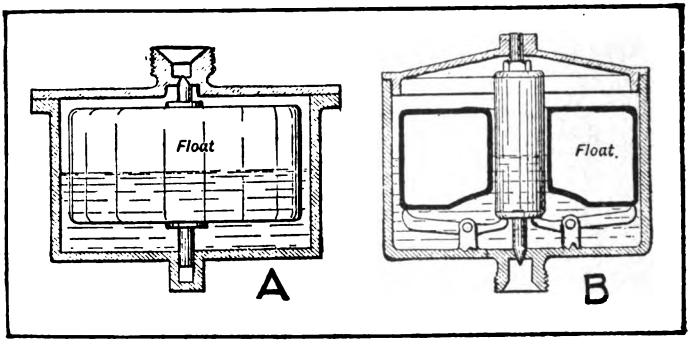

FIG. 61.—Float Chambers Used in Carburetors to Maintain Constant Level at the Jet.

ciples of action are shown at Fig. 61. In that depicted at **A** a cork float carries a needle valve at its center which closes the gasoline opening at the top of the carburetor when the proper level is reached. In the form outlined at **B** the liquid is admitted through the bottom of the float chamber and a system of leverage is necessary to lift the balanced needle valve when the hollow metal float falls.

The fuel control floats are usually either one of the two forms shown. Some authorities favor one method of construction, while others believe that the other form

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of float offers the greatest advantages. The cork float is the simplest and cheapest and is efficient as long as it does not become soaked with fuel and too heavy. The hollow metal float functions satisfactorily as long as it remains tight. If the cork float becomes saturated with liquid it will sink lower in the fuel and the level of gasoline will become too high. A small leak in the hollow metal float will produce the same results by permitting it to fill with fuel. Either form is used successfully, though most of the American carburetor

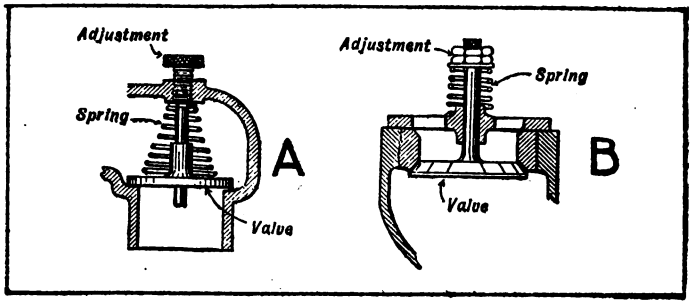

FIG. 62.—Types of Automatic Valves to Admit Auxiliary Air to Mixture.

manufacturers seem to favor the cork float because it is the simplest, cheapest and gives very good satisfaction.

Auxiliary air valves dc not vary much in form, though two methods of construction are followed, as outlined at Fig. 62. That at **A** is a flat seated leather disc valve which is held against its seat by means of an internal spring. The auxiliary valve shown at **B** is the ordinary bevel seated mushroom type of metal and is retained against its seat by an external spring. In most cases some form of adjustment to regulate the supply of auxiliary air is provided. This may be done either

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by increasing the tension of the spring or by some form of stop that will restrict valve movement. In some carburetors, such as that shown at Fig. 63, the auxiliary air is admitted through a series of ports closed by bronze balls of varying weight. The lighter ones are raised from their seats under the influence of light

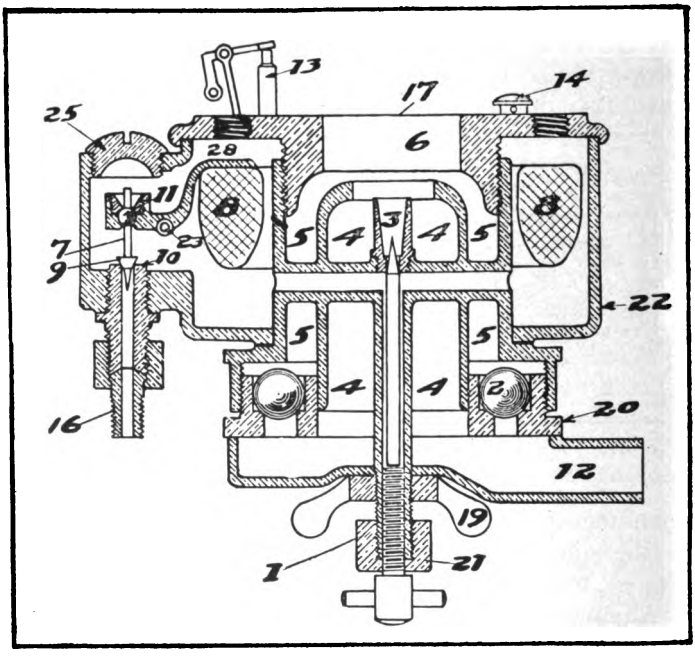

FIG. 63.—Automatic Carburetor Used on Holt Tractor.

suction, and the heavier ones follow progressively as the speed of the engine and degree of suction increases.

Typical Gasoline Carburetors.—The carburetors used on the conventional forms of gas tractors are now practically all of the automatic compensating type. That shown at Fig. 63 is the device used on the Holt

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tractor. It is a concentric float form having gasoline regulation by means of a needle valve and auxiliary air supply by means of a series of ports of varying sizes closed by balls which lift progressively as the suction increases. The gasoline enters through the pipe 16 and its flow is controlled by the needle valve 9 which is pressed against the seat 10 by means of the lever 11 which fulcrums at 23 and which is attached to the cork float 8. When the level of gasoline in the float chamber 22 reaches the height of the top of the standpipe 3, the upward motion of the float 8 imparts a downward motion to the needle valve 9 and brings it against the seat 10. The main air entrance is at 12 and all air entering into the mixture, whether it flows through the central air pipe or through the auxiliary passages, must enter through this opening. The device is coupled to the induction pipe at 6 and when the piston draws in a charge of gas it is composed of air drawn through 12 and gasoline sprayed from the nozzle 3. When the speed of the engine increases and more air is needed the auxiliary air supply enters the mixing chamber through the passages 5 which surround the central air pipe 4.

Another form of carburetor, which is used on the Hart-Parr tractor, is shown at Fig. 64. This view shows not only the carbureting device but the throttling governor that is used to regulate the engine speed. The gasoline is carried in the container (shown for convenience above the mixing device) and is supplied to the float chamber of a concentric carburetor through the usual form of float-controlled valve. Before the liquid enters the float compartment it must pass through a strainer to remove any foreign matter that may be present. The gasoline spray nozzle is controlled by a

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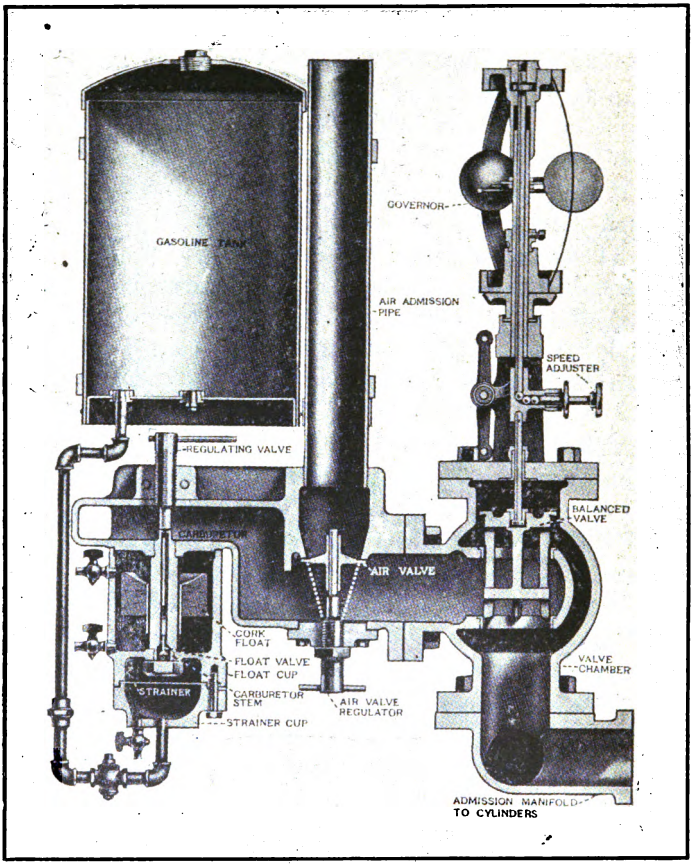

FIG. 64.—Carburetor and Governor of Hart-Parr Design.

regulating valve having a needle point and the amount of gasoline supplied the mixture may thus be easily regulated. The air is drawn in through the vertical air admission pipe, the lower portion of which is controlled by an air valve which opens against spring resistance. In addition to regulating the amount of

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gasoline the mixture proportions may be altered by the air valve regulator provided, which increases the tension of the spring and thus limits the lift of the valve.

Before the gas can flow into the admission manifold, it must pass through a throttle of the piston type. This is connected to a centrifugal governor in such a way that as the governor weights fly out, due to in-

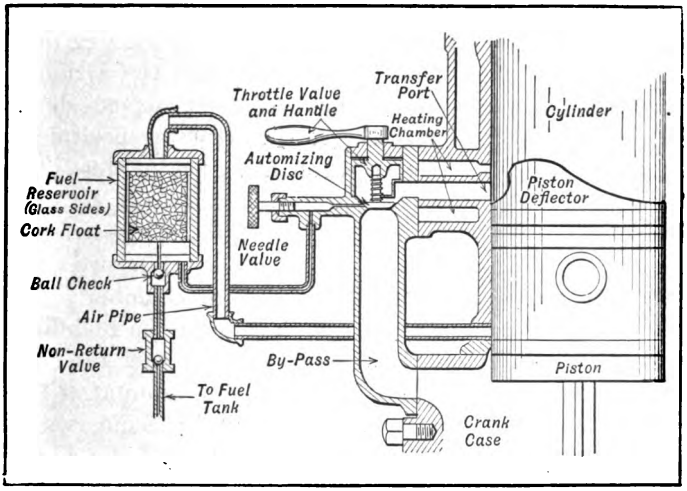

FIG. 65.—Practical Method of Supplying Fuel to Ellis Two Cycle Engine.

creased speed, they draw down on the throttle valve regulating spindle and close the valve, this reducing the amount of gas taken into the cylinder and cutting down the engine speed proportionately. A simple speed adjuster is provided, so that the amount of piston valve travel in relation to the spreading out of the governor weights can be varied at will.

Carburetor for Two-cycle Engine.—A typical

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mixing device, as sometimes supplied with two-cycle engines, is shown at Fig. 65. This is based on the fuel injection principle and while it is not used at the present time on a tractor power plant, the principle of operation is a valuable one and is given because it illustrates clearly another possible method of vaporizing the liquid fuel. The vaporizer shown is used on the Ellis two-cycle stationary power plant and has proven to be very practical and efficient. The device has three principal parts: the fuel reservoir, the atomizing disk, and the heating chamber. In order that the action be more easily understood, the fuel reservoir is shown to one side of the engine, instead of in the position it actually occupies. This reservoir has a heavy plate glass body, through which the fuel level can easily be seen. An air pipe leading from the lower part of the cylinder is connected to the top of the reservoir, while two pipes are attached to the bottom of the float chamber. One of these is the supply pipe, leading from the fuel tank, while the other joins the bottom of the fuel reservoir to the seat of the atomizing disk. The amount of fuel passing to the disk is regulated by a needle valve. The cork float and the fuel reservoir shut off the supply of fuel when the level reaches the proper height as previously described.

As the piston moves upward in the cylinder it produces a suction in the fuel reservoir, this drawing up a supply of liquid from the tank until the fuel reservoir is filled to the proper level. When the piston moves downward, creating compression in the top of the fuel reservoir, the liquid is prevented from returning to the tank by a ball check valve. The atomizing disk regulates the proportions of air and fuel and positively shuts off the liquid when the current of air stops. It also va-

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porizes the liquid by allowing it to be injected under pressure into the moving current of air from the by-pass. The liquid is thus converted into a fine mist, and the vaporized fuel and air are then drawn into and exposed to the intense heat of the heating chamber. Thus carburetion is effected by a combination of mechanical atomization and a vaporizing effect due to heat.

Just before the transfer port is opened by the piston on its downward stroke, the lower edge of the piston uncovers the end of the air pipe leading to the fuel reservoir and the compressed air which is trapped into the top of the float chamber forces the liquid fuel through the opening in the seat of the atomizing disk. As the piston uncovers the transfer port, the compressed air in the crank case, which has been drawn in through a suitable valve when the piston was on its up stroke, rushes past the atomizing disk and atomizes the fuel forced in from the fuel reservoir. The mixture of air and liquid vapor is then directed to the top of the cylinder by the deflector on the piston head. The action is the same as in any two-cycle engine, one explosion being obtained each revolution of the crank shaft.

Action of Kerosene Vaporizer.—In order to insure proper combustion of kerosene when used in carburetors of the conventional form, it is necessary to start the engine on gasoline, until all parts are thoroughly heated. If proper means are taken to heat the carburetor and the intake manifold to prevent condensation of kerosene, it may be used just as soon as the various working parts have been properly heated. A float feed carburetor of conventional design arranged to burn kerosene is shown at Fig. 66. It will be noted that the float chamber is surrounded by a jacket, through which hot water

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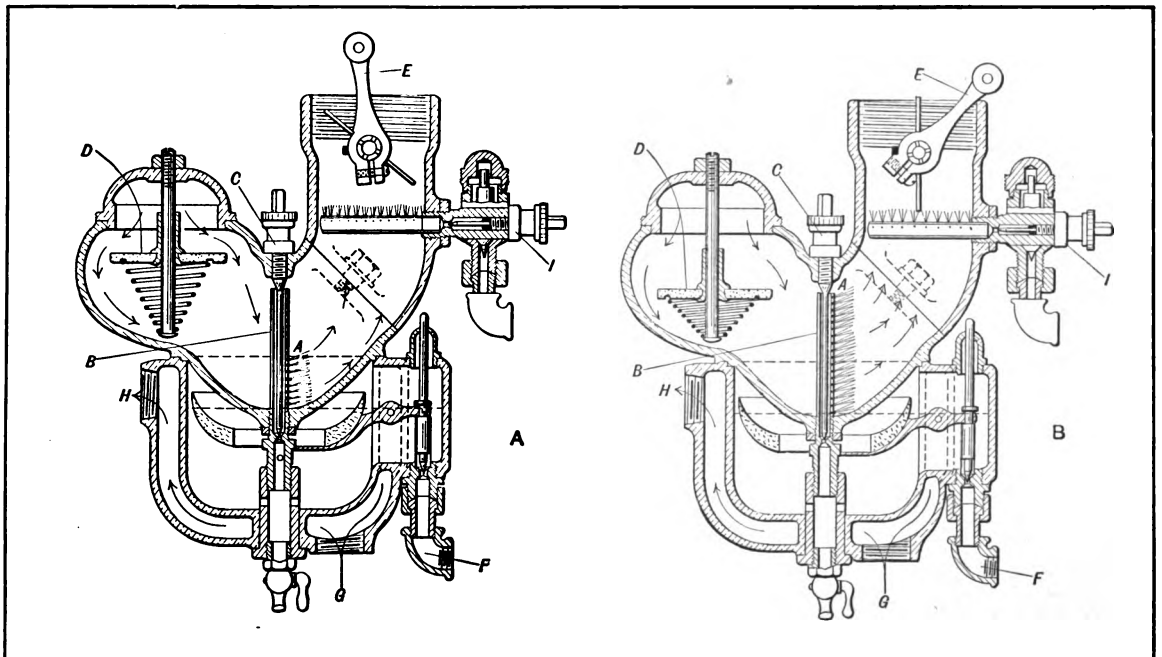

FIG. 66.—Action of Carburetor Used in Gas Traction Company's "Big 4-30" Power Plant When Using Kerosene.

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can enter at G and pass out at H, this heating all parts of the float chamber. The kerosene enters the device through the connection F and passes into the float chamber through the usual form of float controlled valve.

In the ordinary automatic carburetor, as the speed increases and the tendency is to draw in more fuel, an automatic air valve opens to admit an auxiliary supply of air to dilute the liquid. The carburetor illustrated utilizes the auxiliary valve in a different manner. The spray nozzle, instead of being the conventional form, is a small standpipe having numerous fine holes on one side and it is called a spray turret. This is shown at A. At the bottom of the spray member the float bowl upper wall is shaped in such a way that a small pool of liquid fuel is allowed to collect in the bottom. The main air intake is divided and is alone sufficient only to run the motor idle. The air that enters the primary intake passes directly over the pool of fuel and a rich mixture is obtained for starting on. The auxiliary air enters through the opening D and before it enters the cylinders it must pass the spray turret. This lifts the fuel up in the standpipe, where it is drawn through the fine holes in the form of a spray. The greater the amount of air that is passing through, the higher the fuel rises in the spray turret, until with the throttle wide open it is sprayed from all the holes in the standpipe, as indicated at B. The condition with a partially opened throttle is shown at sectional view A and it will be noticed that the kerosene spray is coming through only the holes at the lower part of the standpipe. The amount of liquid sprayed into the mixture is regulated by the needle valve C. In order to burn kerosene successfully water is introduced into

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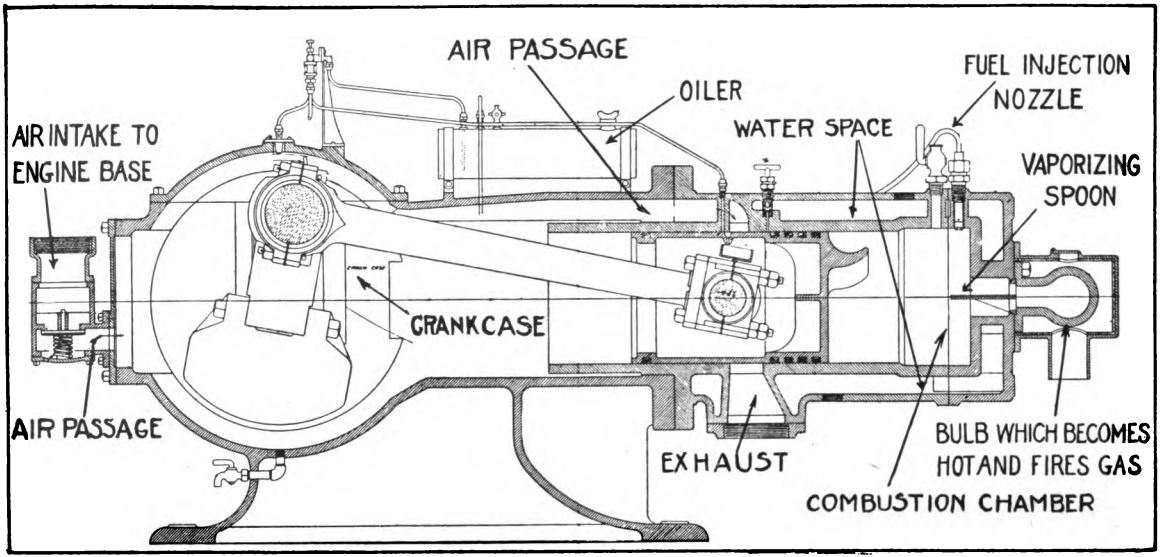

FIG. 67.—How Injected Kerosene is Ignited by Heat in Combustion Chamber. Sectional View of Muncie Two-Cycle Oil Engine.

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the mixture through the auxiliary spray nozzle I. This supplies an extra amount of oxygen and insures a more complete combustion of the kerosene vapor than would be the case if just air was used.

Another method of using the cheaper liquid fuels is shown at Fig. 67, though this is seldom used except on stationary engines designed to run at a constant speed. The liquid is injected into the hot cylinder head through a special fitting when the piston reaches the top of its stroke, and as the fuel strikes the vaporizing spoon, which projects into the combustion chamber, it is vaporized on account of the intense heat of that part. The action of the engine is based on the two-stroke principle. A charge of pure air is drawn into the crank case when the piston is going up on the compression stroke. After the liquid is injected into the combustion chamber, the heat which is present at the end of the compression stroke is sufficiently high to explode the charge of gas without any other means of supplying heat. To start the motor the bulb at the end of the cylinder head is heated by the flame of a gasoline or alcohol torch until it reaches the proper temperature for firing the charge. After the engine is once started the heat is furnished by the successive explosions.

Secor-Higgins Kerosene Carburetor.—The fuel supply system of the Rumely "Oil Pull" tractors is arranged so that kerosene, distillate and other low grade oils may be burned successfully. This, the Secor system, so named after its inventor, does not involve specially designed engines as any motor intended for operation on gasoline can be used successfully with kerosene if fitted with a Secor-Higgins carburetor. This is not a new system, by any means, because it

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was developed over fourteen years ago and has received practical application in thousands of power plants used for agricultural purposes during this period. The following matter, reproduced from the "Scientific American Supplement," clearly outlines the essential features of the Secor system and also of the vaporizer used in connection with it:

"Stated in brief terms, the system covers: (1) An automatic variation in the quantity of fuel mixture in accordance with the slightest variation in speed and load; (2) A degree of compression dependent upon the quantity of the mixture inhaled; (3) A correct proportioning of the mixture under all conditions, involving relatively weaker mixtures for higher compressions and increasingly stronger mixtures for lower compressions; (4) A temperature of combustion exactly adapted to the quality of fuel used and the compression; (5) Automatic control of the internal temperature through the admission of water as part of the fuel mixture; (6) Thorough and uniform mixture of fuel, water and air charge by mechanical means and without the application of additional heat; (7) Automatic variation in the time of firing in response to variations in speed and power; (8) Means for changing the limits of speed within which all factors are simultaneously controlled; (9) And means for starting on a limited supply of volatile fuel, all of which factors are vital to the control of internal heat, the transformation of heat into power and power production. The adaptability of the system described to the lower grade oils is secured through its providing a co-ordination of all factors at all times, this being considered necessary owing to the more difficult vaporization and combination of less volatile oils. The throttling governor,

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taking a different quantity of fuel mixture for each cycle as the load varies, naturally produces a varying compression within the cylinder. It is well known that at higher compression leaner fuel mixtures may be, and should be used, and *vice versa*. One great factor in the success of the system is that through the mechanism of the special carburetor, the proportions of fuel, air and water are automatically varied in relation to each other as the compression changes. By this means the conditions within the cylinder, whether the engine is run at heavy load or light, are constant so far as they affect the completeness of combustion. Complete combustion eliminates the deposit of carbon which has been regarded as an insurmountable objection to the use of heavy fuels, and the unified automatic control results in the securing of splendid regulation.

The automatic control of the quantity of water is an original feature of the system, and is advantageous for several reasons. In the first place it makes for clean combustion by controlling the temperature of vaporization and combustion so that there is practically no cracking of the low-grade oil with its attendant carbon deposit. The water allows the use of higher compression, consequently greater power from the same bore, stroke and speed. The effect of the water in producing a slower-burning mixture is seen in a lower explosion pressure and a flatter indicator card. This results in as high a mean effective pressure as is found in gasoline engines of similar proportions, without the strain and instability produced by a violent initial shock. There is further, undoubtedly, a dissociation of water into nascent hydrogen and oxygen. The latter, being much more active than the diluted oxygen of the atmosphere, has naturally a greater

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affinity for any free carbon that may have been deposited at the moment of explosion. The hydrogen set free probably burns with the oxygen of the air as the temperature falls toward the end of the stroke, but it is doubtful whether enough steam is thus formed to exert any considerable expansive effect upon the piston. The process does, however, effectively scour the cylinder. The explosion is converted into a long, steady push instead of a short, sharp blow, and the water apparently gives an increase of power of at least 15 per cent over a similar engine without it.

The water is not only controlled as to amount, but is brought into play automatically. As the load increases, the throttle opens and more air is sucked through the carburetor. Not until about half load is reached does the suction become strong enough to lift the water, hence it is not present to hinder ignition at light loads, nor to allow preignition at any time, being neither too heavy for ignition at heavy loads nor too light to control the temperature of vaporization.

Crank shaft, cam shaft, governor, magneto, carbureter, valves and piston act as a positively controlled unit in engines equipped with the new system, hence no one mechanical factor deserves to be set apart from the others in importance. However, the special carbureter, which makes possible the application of the new system, is of sufficient novelty to warrant especial attention. A fly-ball governor, through a first-class lever and a link coupling, operates a sliding brass valve which is clearly shown in Fig. 67a. The carbureter sits above the cylinders, with the short inlet manifold presenting little opportunity for the mixture to stratify before it is completely vaporized. It contains constant-level chambers for kerosene and water, an overflow

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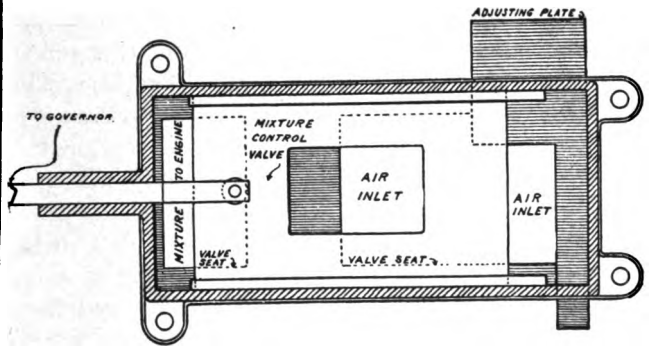
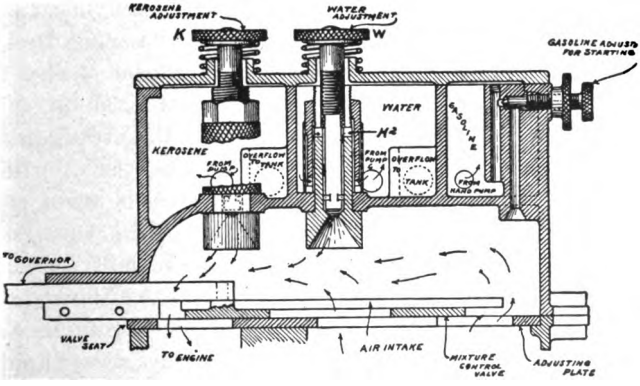


—*Position of sliding valve at light load.*



—*Longitudinal section of carbureter.*

FIG. 67a.—Views of Secor-Higgins Carburetor, Used on Rumely "Oil Pull" Tractors. Position of Sliding Valve at Light Load at Top, Side Sectional View of Device Showing Control Device, Air and Mixture Ports, and Fuel and Water Regulation at Bottom.

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being provided for each. It has also, for starting purposes, a chamber for gasoline which is filled by hand pump. This chamber, which holds about a pint, is connected by a siphon with the mixing chamber. Turning the engine over creates suction enough to draw upon the contents of this chamber, but a vent is provided so that if a start is not made immediately the siphon will not continue to act and drain the chamber.

Fig. 67a shows the position of the valve plate at light load. Two air inlets are then open, providing a large ratio of admission to outlet area and thus greatly reducing the relative vacuum in the mixing chamber. As the load increases, the governor throws the sliding valve forward, increasing the area of the outlet to the cylinder, increasing the air inlet in the middle, and decreasing or entirely closing the air opening at the right. Thus the ratio of admission to outlet area decreases, the relative vacuum becomes greater, and more fuel in quantity, though not in proportion, is picked up by the incoming air and carried to the cylinder.

A sectional view from the side shows the arrangement of the kerosene and water needle valves, the overflow, etc. It will be noted that the water level is lower than the kerosene level. The suction therefore is not great enough, until the engine reaches about half load, to lift the water to the point (H2) where it can flow down the tube surrounding the needle valve. From half to full load, the ratio of water to fuel increases rapidly until the amounts of fuel and water used are practically equal. The carburetor is so designed that the fuel needle-valve (K) should be adjusted at the full-load position, when the plate is farthest to the right. This order of procedure is important, since at this position the adjustable plate has no effect upon the area of the

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air inlet openings. The adjustment of the air should be made at the "no-load" position and after once made, need never be changed, unless the engine enters a very different altitude. This adjustable plate allows each carburetor to be adjusted to the engine it is to serve, hence the slight variations in manufacturing are fully taken care of. The sliding plate is the only moving part in the carburetor, and that is positively controlled. There are no springs, floats or check valves. The device is simple, the parts are large and there is no possibility of the device getting out of order or failing to supply a correctly proportioned mixture as long as the pumps supplying fuel and water are functioning properly and the fuel and water containers are kept full.

Methods of Exploding Charge.—When the gas engine was first developed the compressed gas was exploded by means of a naked flame which was permitted to communicate with the combustion chamber by means of a slide valve which moved at the proper time to permit the flame to ignite the gas back of the piston. This system of ignition was practical only on the primitive gas engines where the charge was not compressed to any degree. When it became desirable to compress the gas before firing it, the hot tube system of ignition was used. This method involved the use of an incandescent platinum, porcelain or nickel tube in the combustion chamber, the tube or ignitor being kept in a heated condition by a flame burning in it. Another method which has been previously described, and which is illustrated at Fig. 61, depends upon the property of gases firing themselves if compressed to a sufficient degree, provided that a certain amount of heat was stored in the cylinder head to insure complete vaporization of the gas and help produce the proper kindling temperature.

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Advantages of Electrical Ignition.—Practically all of the gas engines in use at the present time, except a few employed in the oil fields, utilize electrical ignition systems. In all tractor power plants the compressed gas is exploded by a minute electric arc or spark in the cylinder, the current for which is produced by some form of chemical or mechanical generator of electricity. The early forms of ignition systems had a disadvantage in that they were not flexible and could be used successfully only on constant speed engines. None of these methods are practical in connection with gas tractor power plants because they do not permit the flexible engine action that is so desirable.

While electrical ignition systems are somewhat more complicated than the other simpler types, they are the most efficient, and as their peculiarities are now generally understood, there is no difficulty in applying them successfully. Two forms of electric ignition systems are in general use, the most popular being that in which a current of electricity under high potential or pressure is forced to leap an air space between the points of a spark plug which is screwed into the cylinder. The other system, which is used to a limited extent on gas tractor engines, is known as the low tension system because a current of comparatively low voltage is utilized instead of the high pressure current used in the more popular systems. Whereas the spark is produced in the high tension system by the current heating up the air particles between the points of the spark plug, it is produced in the combustion chamber when the low tension method is employed by moving electrodes which come in contact with each other and which produce a spark as they separate.

The essential elements of any electrical ignition

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system are: First, a simple and practical method of current production; second, suitable timing apparatus to cause the spark to occur at the right point in the cycle of engine action; third, some form of igniter to produce the spark in the combustion chamber; fourth, apparatus to transform the low tension current obtained from batteries or dynamo to one of greater value before it can produce a spark in the cylinder; and fifth, suitable wiring, switches and other apparatus to convey the current produced by the generator to the auxiliary apparatus and from these to the spark producing member in the cylinder head.

Methods of Producing Current.—There are two common means for obtaining the electrical current used to produce the spark in the cylinder, one of these depending on a chemical action, the other an electromagnetic action. The first class includes the various forms of primary and secondary batteries, while the second group includes the various mechanical appliances, such as dynamos and magnetos.

Dry and Storage Batteries.—The simplest method of current generation, and the cheapest as well, is by means of a simple chemical cell, generally known as the "dry battery." These belong to the primary cell class because a current of electricity is generated by the oxidation of one of the elements of which the cell is composed by the electrolyte. Any primary battery consists of three main elements: First, a plate of some material which will be acted on by the electrolyte. Second, an electrolyte which may be a solution of a salt or acid in water, which will have a chemical affinity for the active element. Third, a neutral plate which serves to collect the electricity produced by the chemical combination of the electrolyte and active elements.

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The dry battery is so called because the electrolyte is in the form of a paste instead of a liquid. The dry cell consists of a zinc can filled with electrolyte and a depolarizing chemical in the center of which a carbon rod or plate is placed. The function of the depolarizer is to keep the cells active for a longer period than would be the case if only a simple electrolyte was used. The zinc can serves as a container for the electrolyte and also forms the active member. The carbon rod is the neutral or collecting member. A terminal is attached to the zinc can and is known as the negative, commonly indicated by a minus sign thus (—) while the terminal attached to the carbon is known as the positive connection (commonly indicated by a plus sign (+). It is to these terminals that the wires forming the external circuit of the cell are attached, the internal circuit being completed by the electrolyte and depolarizer.

A single dry cell does not have enough power to produce a spark, so a number of these are generally joined to form a battery. The common method of connecting dry cells is in series; this means that the positive terminal of one cell is always coupled to the negative terminal of its neighbor. When cells are coupled in this manner, the battery has a voltage equal to that of one cell times the number of cells so joined. For instance, four dry cells would have a potential or current pressure of six volts, as one dry cell has a pressure of one and one-half volts. The amount of current produced by the batteries is measured in amperes and the battery capacity will depend upon the size of the active element and the strength of the electrolyte. The ordinary No. 6 dry cell which is six inches high by two and one-half inches in diameter will indicate a current strength of about twenty amperes. When

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cells are joined in series the amperage of the set is equal to that of but one cell. If it is desired to obtain greater amperage, the cells are joined in multiple, which means that all terminals of similar polarity are joined together. A battery of four dry cells connected in this manner would deliver a current of about eighty amperes.

When dry batteries are used for ignition purposes, they are generally coupled together in a series-multiple connection to obtain the proper voltage and current strength. The dry battery has a number of advantages, chief among which are its cheapness, ease of installation, compactness and simplicity. It has the disadvantage of being limited in capacity and not suited for continuous work, which it shares with all other forms of primary battery. When dry cells are exhausted there is no method of renewing them to efficiency and they must be replaced. This is not a serious factor, however, as an entire new set of six cells will cost but $1.50.

The storage battery is a chemical current producer that is capable of being recharged when it is exhausted by passing a current of electricity through it in a reverse direction to that of the current given out. Storage batteries are composed of elements of practically the same material and can only become active when a current of electricity is passed through them. The materials generally used are grids of lead filled with a paste composed of lead oxide. When the current of electricity passes through these plates, they become enough different in nature so that a difference of electrical condition exists between them, and when the cell is fully charged, a current may be drawn from it in just the same way as from a primary battery.

Storage batteries have the advantage that they may

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be used for continuous current production, and as they may be recharged when exhausted, it is not necessary to replace them with new members when they will no longer produce current. The storage battery is called a "secondary cell" because it can only give out energy after a current of electricity has passed through it, whereas a primary battery in good condition will produce electricity as soon as it is completed. The storage battery uses an electrolyte composed of dilute sulphuric acid and water, while a dry battery uses an alkaline electrolyte composed largely of sal-ammoniac and chloride of zinc.

The average form of storage battery used for ignition purposes is really composed of three cells, which are placed in a common carrying case of wood or hard rubber. The connection between the cells is made by plates of lead which are burned to the elements, leaving but two terminals free, one of which is a negative member while the other leads from the positive plates. To prevent spilling of the electrolyte the top of the cell or battery is sealed with a hard rubber plate over which is poured a pitch and rosin compound. The electrolyte is renewed through a small vent in each cell which is covered by a removable hard rubber cap. These vents also allow for the escape of the gases evolved when the cell is being charged or when it is delivering a current of electricity. The average ignition battery has a capacity of 60 to 80 ampere hours and a current pressure of about 6.6 volts when fully charged.

Functions of Induction Coil.—The current obtained from a dry or storage battery is not sufficiently powerful to leap the gap that exists between the points of a spark plug utilized in the high tension ignition system. This space offers a resistance to the passage

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of the current that requires a pressure of several thousand volts to overcome, and as the ordinary ignition battery produces but six volts it will be apparent that unless the current strength is increased it could not overcome the resistance of the air gap between the spark plug points. A simple device known as an "induction coil" is employed to transform the low tension battery current to a current of sufficient voltage to jump the air gap at the plug. The current from the battery is first passed through the primary coil, which is composed of several layers of coarse wire wound around a core of lengths of soft iron wire to form an electro-magnet. Another coil composed of a large number of turns of finer wire is wound over the primary coil. When a current of electricity of low voltage passes through the primary coil, a current of high electro-motive force is delivered from the terminals of the secondary winding.

The induction coil is usually provided with a device known as a "vibrator," which is an automatic circuit breaker actuated by the magnetism of the core. Every time the circuit is made and broken at the vibrator contact points an electrical impulse is induced at the secondary winding, and the more rapid the vibration, the greater the number of impulses in the secondary current. A simple coil, such as used for single cylinder ignition, is shown at Fig. 68. As will be seen, three terminals are provided on the coil exterior, one leading to the battery, one to the commutator, and the remaining one to the spark plug. The vibrator spring **A** carries one of the contact points and the knurled head adujsting screw **B** carries the other. The amplitude of vibration is varied by moving the adjusting screw **B** or by increasing or decreasing the strength

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of the vibrator spring. An induction coil for use with a multiple cylinder engine is composed of a number of simple coils fastened together in a common case and having enough terminals to make the proper connections in the outer circuit, as will be described in proper sequence. When the vibrator is in operation it moves so rapidly that it makes a buzz like that of some fast flying insect and when properly adjusted it may even give a definite musical note. If the vibrator action is

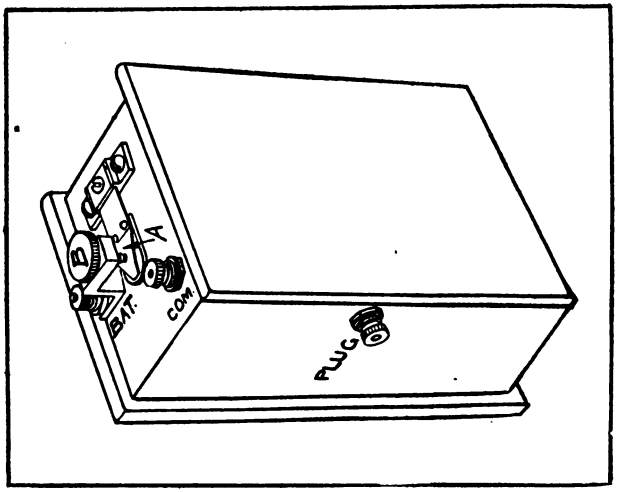

FIG. 68.—Induction Coil Used in Connection With Batteries to Produce Electric Spark in Gas Engine Cylinder.

not rapid the amount of secondary current produced will not be as great nor will it have as high voltage because the current output is dependent not only upon the number of impulses flowing through the primary coil but also upon the rapidity of the contacts at the vibrator.

Producing Spark in Cylinders.—The two common

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appliances for producing an electric spark in the combustion chamber are shown at Fig. 69. That at A is a low tension igniter plate having a movable electrode. One of the spark points is carried in a fixed member or anvil which is shown detached so the construction may be understood and which is installed in and insulated from the main body of the igniter plate. The movable member, which is actuated by a bell crank, carries the other contact point and is normally in contact with the anvil. When it is desired to produce

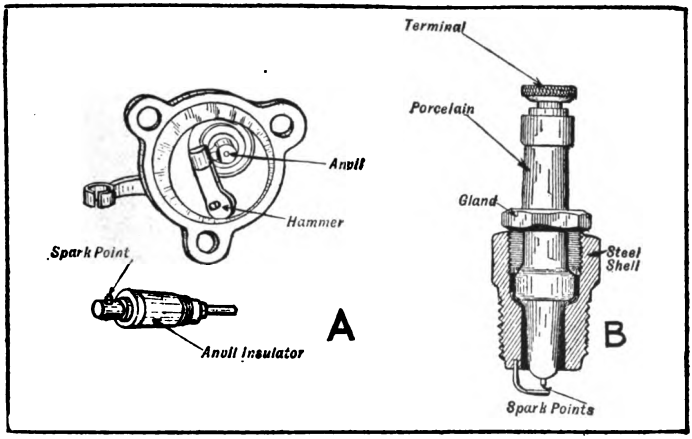

FIG. 69.—Devices for Producing Spark in Engine Cylinder. *A*—Low Tension Igniter Plate. *B*—High Tension Spark Plug.

a spark the hammer is pulled away from the anvil by some mechanical means, usually a tappet rod operated by a plunger and cam in just the same manner as a valve is lifted. At the instant of breaking contact a hot spark takes place between the points and this explodes the mixture. There are other forms of low tension igniters but the type described is the most

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common, and has demonstrated that it is the most practical.

The obvious disadvantage of this construction is that the moving member in the hot combustion chamber may become fouled with carbon, or the points may become burnt and covered with scale to such an extent that the electrical connection made when they touch will be very poor. Then, as is true of all moving mechanism, the factor of deterioration enters into consideration. Considerable difficulty is experienced in keeping the joint around the hammer spindle tight and the result is that as soon as this wears the action of the igniter becomes erratic and mixture troubles may result due to dilution of the charge by air which leaks into the combustion chamber through the worn hammer bearing.

The factor of wear is an important one in that it also affects the timing and on a multiple cylinder engine it may be found difficult to secure proper firing of all the cylinders. Those in which the mechanism is worn most will not fire at the same relative time in the cycle of operations as will the other members that are not worn so much. The result of the explosions not following in regular sequence is irregular engine operation and lack of smoothness in power delivery. Low tension igniters are entirely practical on simple forms of low speed engines but are not suited to higher speed multiple cylinder power plants.

One of the marked advantages of the low tension ignition system is that it will produce a spark having a greater heat value than will the ordinary high tension system. This advantage is of some moment when using the lower grade fuels that will not ignite as readily as will a gasoline vapor. It is claimed by those who

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favor the low tension system of ignition that it will ignite a greater range of mixtures than the thinner and less hot high tension spark.

The simplicity of the conventional form of spark plug used with the various high tension ignition systems is clearly outlined at Fig. 69-B. Not only is the device more simple than the low tension igniter plate but it has no moving parts. It will be seen that the main member of the plug is a steel shell, which is provided with a thread at the bottom by which the plug is screwed into the cylinder. One of the electrodes is attached to this shell as indicated. The other electrode is in the form of a light rod or wire, carried through the center of some insulating medium which in this case is a porcelain bushing. This bushing is capped with a terminal nut by which the device is connected into the outer circuit. The porcelain insulator is held against a packing or gasket by a threaded gland which screws into the upper portion of a plug body.

Spark plug construction varies widely, but all operate on exactly the same principle. The arrangement of spark points may be different and mica or glass may be used instead of porcelain insulation, but the action remains the same. As will be evident, the only parts of the plug that are exposed to the hot gases are the spark points and the lower portion of the porcelain insulating bushing. There is practically no part that will cause trouble or that will wear in service and the device needs but little attention after it is once installed. Even if it should fail to work because of a cracked insulator or a defective spark point the entire device may be renewed for fifty or seventy-five cents and, as is true of the dry cell battery, it is often cheaper to renew them than to attempt to make repairs.

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In most forms of spark plugs the porcelain is easy to remove and if a spare insulator is at hand it may be readily substituted for the imperfect ones by anybody who is able to handle a wrench. There is no more or less complicated mechanism to time and if the insulator is kept free from carbon and soot and the spark points separated by the proper gap, there is no opportunity for irregular ignition. As the spark plug may be screwed tightly into the cylinder it is easy to obtain a gas tight joint, and the mixture troubles and hissing incidental to worn igniter plates are not present.

Mechanical Generator Advantages.—Taking electricity from either a dry or storage battery is comparable to drawing a liquid from a reservoir filled with a certain definite supply. As the demands upon the reservoir increase, its capacity and the amount of liquid it contains become less in direct proportion. Batteries cannot maintain a constant output of electricity for an indefinite period and their strength is reduced according to the amount of service they give. A mechanical generator of electricity produces current without any actual deterioration or depreciation of chemicals and plates, as is true of a battery. There is some wear present in a mechanical generator but this is so small compared to the amount of service it will give that its effect is practically negligible as regards current output.

A simple analogy that will enable one to appreciate the merits of the mechanical generator may be made with a pump system of drawing a liquid from a practically inexhaustible reservoir. As long as the pump is turned it will supply liquid. The same thing is true of a mechanical generator of electricity which will

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supply current as long as the rotating parts are turned. With batteries, when the engine speed increases and the demands upon them become greater the current strength decreases at a time it should be strong. With a mechanical generator of electricity the current output increases as the speed, and as these devices are usually driven directly from the engine, when this member demands more electricity the mechanical generator will supply it automatically because it is being driven faster.

Types of Magnetos.—There are two forms of mechanical generators commonly used and the principle of action is somewhat the same. They differ widely, however, in construction and method of application. The first forms used to replace batteries were patterned after the dynamo electric machines used for supplying current for electric lighting and other industrial purposes. The dynamo was later simplified by the elimination of one set of windings and it was made lighter and more efficient. This form of mechanical generator is called a "magneto" because permanent magnets are utilized instead of wire wound or electro magnets. The dynamo form of generator is used where currents of considerable value are needed, while the magneto is generally applied for ignition purposes. Another advantage of the magneto is that it may be made so it will contain a complete ignition system in itself, whereas when a dynamo is employed practically the same conditions obtain as though batteries were used. The dynamo merely replaces the chemical current producer.

A mechanical generator of electricity produces current by an induction action. It is a known fact that if an insulated wire is wound around a bar of iron or steel and a current of electricity is passed through it,

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the metal will become magnetized, i. e., it possesses the property of attracting other pieces of iron or steel to it. As a current of electricity flowing through a wire wound around a bar of steel will make a magnet of it, if a magnet is inserted into an inactive coil of wire it will generate a current of electricity by a reversal of the phenomena first mentioned. In other words, a current of electricity will be produced in a conductor by a magnet if either of these is moved in such a way

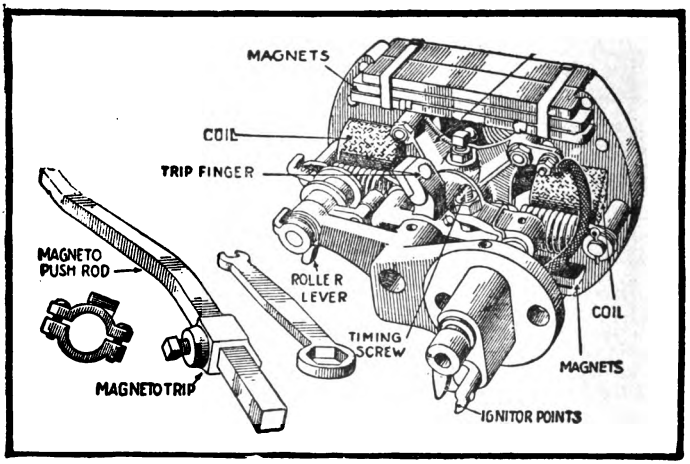

FIG. 70.—Oscillating Armature Low Tension Magneto and Integral Igniter Plate a Complete Ignition System.

that the field of magnetic influence is traversed or cut by the wire. In a dynamo or magneto a number of coils of wire are mounted on a revolving member, termed the armature, which is placed between the pole pieces of the energizing or field magnet. The faster the armature rotates, the more rapidly do the armature windings pass through the magnetic field and the greater the number of electrical impulses produced because one of these

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is created every time a loop of wire passes through the magnetic field.

Oscillating Armature Forms.—The armature of a magneto is not always a revolving member except when this device is used to produce a continuous flow of current. In some ignition systems a single electric impulse is all that is needed to produce the spark. A number of low tension magnetos are made on the oscillating armature principle. One of these is clearly shown at Fig. 70. Instead of the armature being a revolving member it is an oscillating member and does not make a complete revolution. In the device shown the armature is replaced by an inductor member which carries no wire and which oscillates freely between the pole pieces of the magnets. The form depicted is really a unit with the igniter plug and is adapted to be bolted to the side of the cylinder in such a way that while the igniter points project into the combustion chamber, the device is in a position close to the cylinder head where it may be readily operated by means of a push-rod and trip from the engine cam shaft.

The device is so arranged that when a spark is desired between the ignitor points, the inductor is given a quick movement which produces a flow of magnetic energy through the windings. At the same instant that the flow of electricity takes place through the coils, the ignitor points are separated and a spark is produced in the cylinder. The action of a device of this character is automatic, and each time that the magneto push-rod trips the inductor the points of the ignitor separate and a spark is obtained to ignite the compressed gas.

It is apparent that this method of current generation will take but very little power from the engine and that there can be no depreciation that will tend to

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diminish the amount of current at a time that the engine needs a hot, fat spark. This device forms a complete ignition system and is suitable for practically all stationary engines of the single cylinder or two cylinder patterns. It would not be advisable to furnish this form of magneto for more than two cylinders because a separate device is needed for each cylinder and the mechanical complication incidental to the use of four of these devices with the trip rods, etc., would not be desirable.

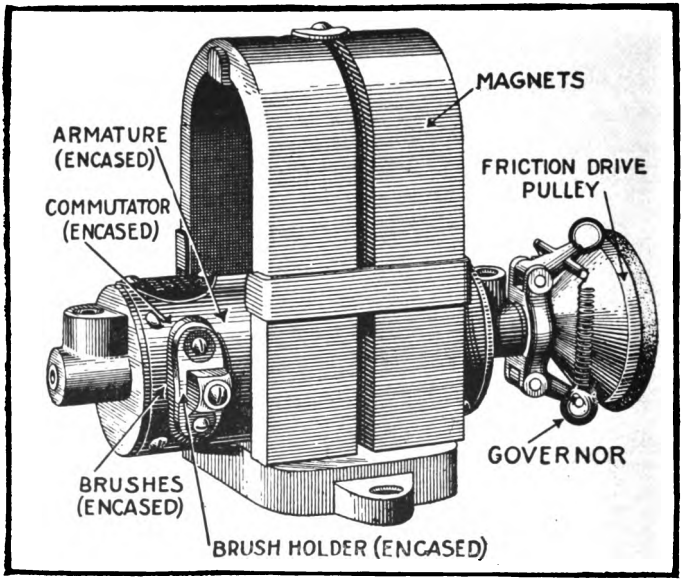

FIG. 71.—Revolving Armature Magneto Delivering Low Tension Current. Used in Connection With Induction Coil, Timer and Spark Plug to Form Complete Ignition System.

Type With Revolving Armature.—The revolving armature type of magneto is the form that is generally used for supplying current whenever a constant flow

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is desired. When a device of this nature is intended to replace batteries it is of the low tension direct current form, as shown at Fig. 71. The magnetic field is produced by a pair of permanent magnets attached to pole pieces between which the armature revolves. The electricity produced in the coils of wire in the armature is collected by means of two brushes which form the terminals corresponding to the positive and negative poles of a battery. As a device of this character is intended to be driven at a constant speed, an automatic governor is usually provided which becomes inoperative when the safe speed of magneto rotation is exceeded.

The form shown is intended to be driven by means of a friction drive pulley bearing against the flywheel. This pulley drives the armature by frictional contact between the governor arms and the outer tapered face of the drive pulley.. This member is faced with fiber or leather where it bears against the engine flywheel in order to secure greater frictional adhesion. The governor arms are carried by a fitting which is attached to the armature shaft, while the friction drive pulley is free to rotate on the armature shaft except at those times when the governor arms are in contact with its face. When the speed increases to a point where the governor arms will fly out because the centrifugal force is greater than the tension of the coil springs holding them in contact with the pulley, the drive is interrupted, and the friction drive pulley turns at one speed while the armature, which now revolves only by its own momentum, tends to slow down. The armature speed finally slackens to a point where centrifugal force is not strong enough to keep the weighted governor arms out of contact with the friction drive pulley. The tension springs then act and the armature is driven from

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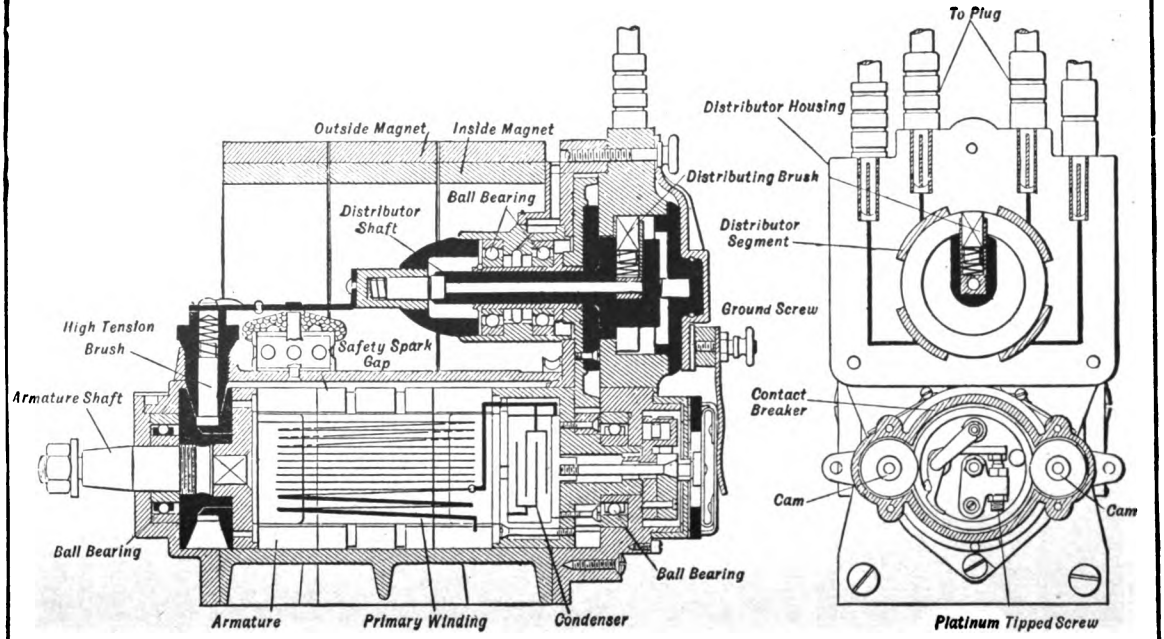

FIG. 72.—Sectional View of Bosch High Tension Magneto, a Complete Current Producer for Four Cylinder Engine Ignition.

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the friction pulley until the safe speed is again exceeded at which time the driving connection will be automatically broken again. The device shown is wired into the circuit just as the set of batteries would be and an induction coil and timer will be needed to complete the ignition system.

High Tension Device.—The high tension magneto is the form that is generally used in automobile ignition systems and its popularity is increasing among gas tractor manufacturers as well. The advantages of the true high tension magneto are that it comprises in one device all the elements of the current generating and intensifying devices and all that is needed in connection with a high tension magneto are the spark plugs and the wires by which they are connected to the instrument. A high tension magneto for a four cylinder engine is but very little more complicated than one used on a two cylinder power plant. The only difference is in the number of contacts in the distributor and the speed at which the device is driven.

A typical high tension magneto utilized in connection with a four cylinder engine is outlined at Fig. 72 and all the parts are clearly shown. The armature is a two pole type having an approximately **H** section and it is wound with two coils of wire. One of these is a comparatively coarse one corresponding to the primary winding of an induction coil, while the other is a fine winding having many turns that correspond to the secondary coil. The armature shaft is mounted on ball bearings to insure easy rotation. The magnetic field is produced by means of three pairs of horseshoe magnets which are attached to pole pieces which form the armature tunnel. Mounted on and turning with the armature is a condenser which is placed in shunt con-

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nection with the contact points in the magneto breaker box. The armature is driven by means of positive chain or gear drive and it is timed in such a way that the contact points of the magneto contact breaker separate only when a spark is desired in the engine.

On a four cylinder motor the magneto is driven at crankshaft speed, the contact breaker cams being arranged in such a manner that the contact points separate twice during each revolution of the armature. Every time the contact points are separated a current of electricity leaves the armature by means of a high tension brush which bears on the insulated contact ring carried at one end of the armature shaft and is led to a distributing brush at the center of the secondary current distributing member. The spark plugs are attached to wires which lead to the segments in the distributor, there being one segment for each spark plug. The distributor shaft is revolved at half armature speed by means of gears and the revolving contact brush makes contact with one of the segments each time that the spark points separate, so that the current of electricity is directed to the plug which is in the cylinder about to fire. It will be seen that this device includes the current generating and commutating means as well as the timing mechanism.

A magneto for a two cylinder engine would have but two distributor segments and would be driven at camshaft speed or half that of the crank shaft. A magneto for a three cylinder engine would have the segments spaced 120 degrees apart in the distributor and would be driven at three-quarters crankshaft speed. On a six cylinder motor the magneto would be driven at one and one-half times crankshaft speed and there would be six segments in the distributor, spaced 60 degrees

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apart. In the four cylinder form shown the distributor segments are arranged on quarters of the circle or 90 degrees apart.

The contact breaker, which corresponds to the timer of a battery ignition system, consists of a fixed member which carries one of the platinum contact screws while the movable bellcrank lever carries the other platinum contact. The condenser is used to absorb a surplus current which is due to self induction between the various windings of wire and to prevent the excess current so generated from producing a spark that would tend to burn the contact points as they separate. The safety spark gap is interposed between the high tension brush and the ground in such a way that any excess current that might injure the windings if it was allowed to go through the instrument in the regular manner will be allowed to flow to the ground without passing through the external circuit. This device performs the same function for the magneto as a safety valve does for a steam boiler, in that it provides a means of escape for excess pressure that might injure the device if no means were provided for its disposal other than the regular channels of distribution. The action of the magneto ignition system will be described more in detail when considering the operation of complete ignition groups.

Low Tension Ignition Systems.—The practical application of a low tension ignition system to a four cylinder engine is clearly outlined at Fig. 73. Two sources of current are provided, one a mechanical generator while the other is a battery of ten dry cells in series. A two-way switch is provided so either battery or magneto may be used as desired. As a general rule the magneto is used for regular ignition and the battery

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is called upon to deliver current only for starting and in event of emergencies in which the mechanical generator might get out of order. The four igniters are connected to a common conductor or bus bar which is insulated from the metal portions of the engine and which is connected to the top of the switch lever by means of a single wire. A wire runs from the magneto collector brush to one side of the switch, while a conductor from the spark coil, which is in series with the batteries, connects to the other side of the switch. One of

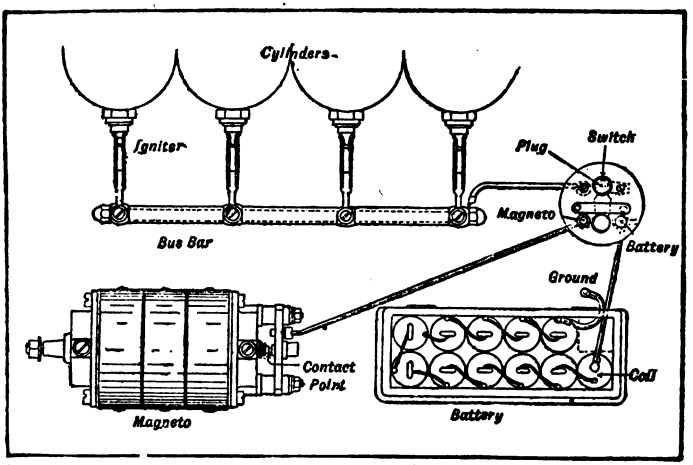

FIG. 73.—Typical Four Cylinder Low Tension Ignition System.

the battery terminals is attached to the frame or base of the engine and one of the magneto leads is also grounded.

It will be evident that when the switch lever is in central position, as shown, neither magneto nor battery and coil set is in service and that there can be no spark in the cylinder. If the switch lever is placed on one contact button the battery ignition system can be

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used, and if it is moved to the other contact button, the current for ignition will be obtained from the mechanical generator.

Simple Battery Ignition Methods.—The components of a simple battery ignition system are shown in outline form at Fig. 74, the ignition system being that for a single cylinder engine. As is true of the low tension system previously described, two methods of current generation are provided, a two-way switch being in-

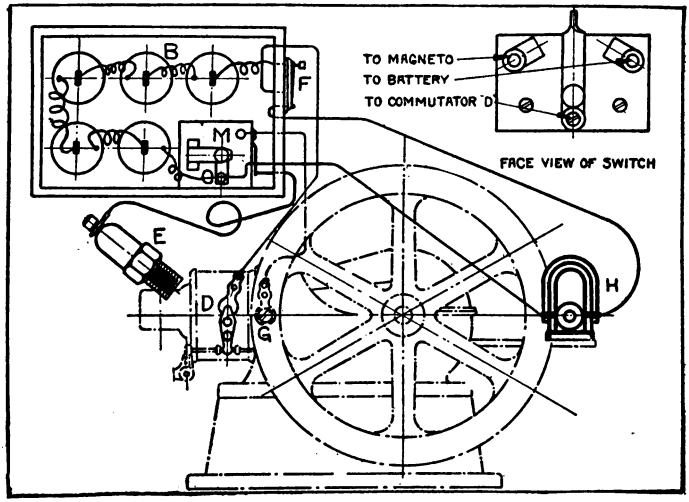

FIG. 74.—Simple Ignition System for One Cylinder Engine Using Battery and Magneto.

stalled in the circuit of both magneto and battery leads. The switch **F** is attached to the outside of the battery box, which carries the dry cells **B** and the induction coil **M**. The secondary terminal of the induction coil is attached to spark plug **E** which is placed in the combustion chamber of the cylinder. One terminal of the induction coil **M** is grounded on the engine, as

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at G. The central terminal of the switch F goes to the insulated terminal of the timer D. One of the leads of the battery D is attached to one of the contact buttons of the switch while the other goes to the remaining primary terminal of the induction coil.

The magneto H is similarly connected, one of the

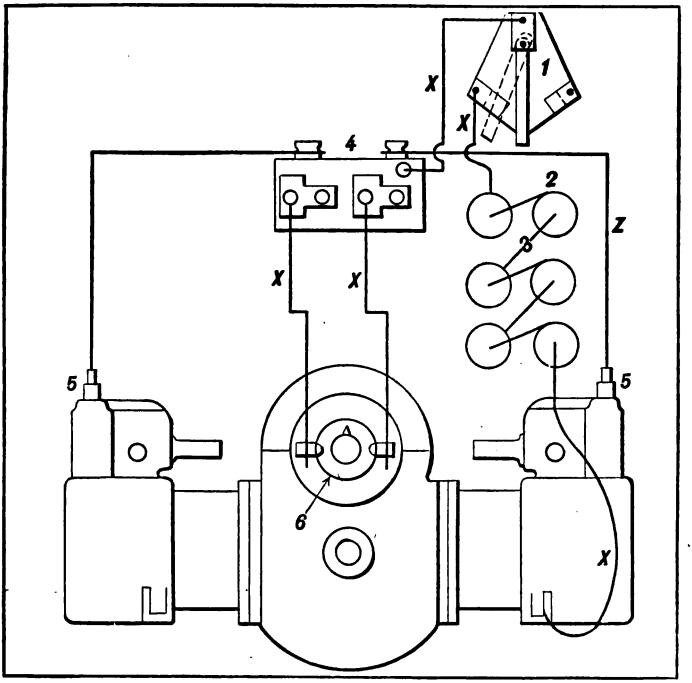

FIG. 75.—Two Cylinder Battery and Coil Ignition System.

leads going to one side of the switch while the other goes to the primary terminals of the coil M. Either magneto or battery may be used, depending upon the position of the switch lever. When the switch is thrown in contact the circuit is still broken until such time that

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the timer **D** makes contact between the two members. When this occurs the current from the battery or magneto, depending upon which is thrown in circuit at the switch, will pass through the primary coil of the induction coil **M**. This produces a secondary current of sufficient magnitude to produce a spark between the points of the spark plug **E**. As soon as the timer breaks contact the primary circuit is interrupted and the spark between the points of the spark plug ceases. In actual practice contact at the timer **D** is established only for an instant every two revolutions of the crankshaft and the parts are arranged and timed in such a manner that the spark takes place only when the piston has reached the end of its compression stroke and the compressed charge of gas is ready to be exploded.

The ignition system for a two cylinder opposed engine is outlined in diagram form at Fig. 75. In this the only source of current supply is a set of six dry cells, wired in series. The switch is a two-point type and either a battery or magneto may be coupled to the free terminal just the same as in the simple ignition system previously described. The spark coil, which is the transformer form used in the high tension ignition system, is composed of two distinct units wired together in a common case leaving five exposed terminals. Those located at the top of the coil are joined to the primary circuit, one of the three that is marked "battery" going to the central terminal of the switch while the other two that are marked "commutator" (com.) are attached to the insulated terminals of the two-point timer. The two terminals at the side of the coil are high tension leads, one for each coil unit, and are joined to the spark plugs by the usual form of conductor. With this system each unit of the coil fires one of the cylinders and the

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two-point timer serves to establish the circuit required to produce a spark at the proper time. As the explosions occur in regular order the contact points of the timer, which is driven at half the engine speed, are spaced on the halves of the circle or 180 degrees apart.

A typical four cylinder ignition system in which batteries alone are employed to generate electricity is clearly

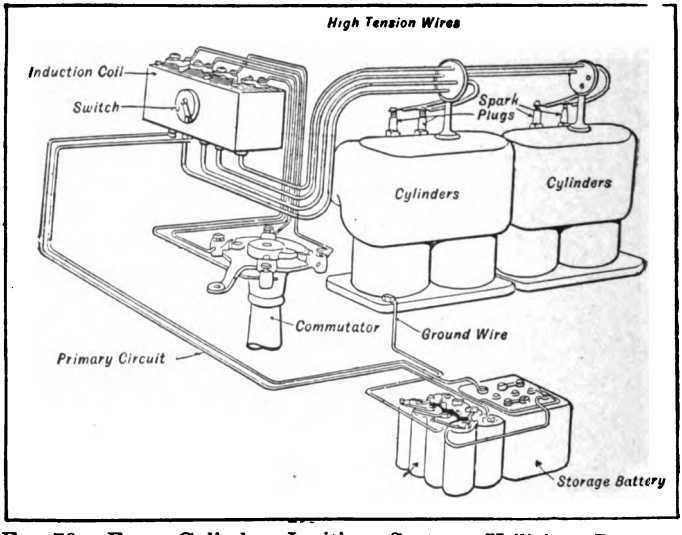

FIG. 76.—Four Cylinder Ignition System Utilizing Battery Current.

outlined at Fig. 76. The commutator, or timer in this case, is a four point type, having four insulated contacts and one revolving member which establishes the proper connection with each of the insulated members as it revolves. The timer is driven at half of the crankshaft speed, and as two explosions occur each revolution the insulated timer segments are spaced ninety degrees apart. The induction coil employed is a four unit type.

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The four individual members are carried in a common case and wired so a minimum number of terminals to which wires must be attached are on the outside of the case. The switch, which is a two point type, is mounted on the face of the induction coil box. Two sets of batteries are provided, one of the dry cell form, the other a six volt storage battery. The negative terminals of both storage battery and dry battery are joined by a common wire which is grounded on the engine base. The positive terminals of each battery are led to the two primary terminals immediately under the switch at the bottom of the coil. Four large, well insulated wires lead from the bottom of the coil to the cylinders, while the four primary conductors join the insulated contact members of the timer and the primary terminals at the top of the coil.

The central revolving member of the timer is grounded so that the effect, as far as the circuit is concerned, is just as though the negative wire from both sets of batteries were connected directly with it. When the switch lever is placed on the button at the right, the storage battery is thrown in the circuit and the ignition current for regular running is obtained. When the lever is switched over to the other side the dry batteries, which are usually reserved for emergency duty, are put into action. The operation of this system is identical with that of the simple one cylinder ignition system, previously considered, excepting that the various units of the coil are brought into the circuit progressively in the proper firing order. The four cylinder engine illustrated has a firing order of 1, 2, 4, 3. The front cylinder fires first during the first half of the first revolution of the crankshaft, while the second cylinder, which is the one immediately back of it, fires during the second half

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of the first revolution of the crankshaft. The fourth cylinder delivers a power stroke during the first half of the second revolution, this being followed by the third cylinder, which delivers power to the crankshaft the second half of the second revolution.

Action of Magneto Ignition Systems.—In order to simplify the explanation of the action of a typical

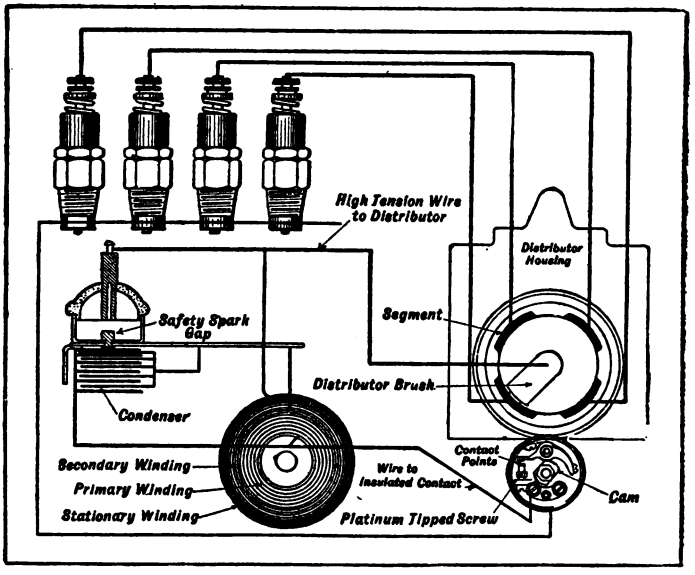

FIG. 77.—Diagram Explaning Action of Four Cylinder Magneto Ignition System Used on "Big 4-30" Gas Tractor.

high tension magneto, the various essential parts that are in circuit are shown at Fig. 77. The magneto shown has a revolving inductor member instead of the conventional form of armature and a stationary double coil mounted in the center of the device in such a way that the magnetic influence from the field magnet is directed through the coil at the time that a spark is desired in

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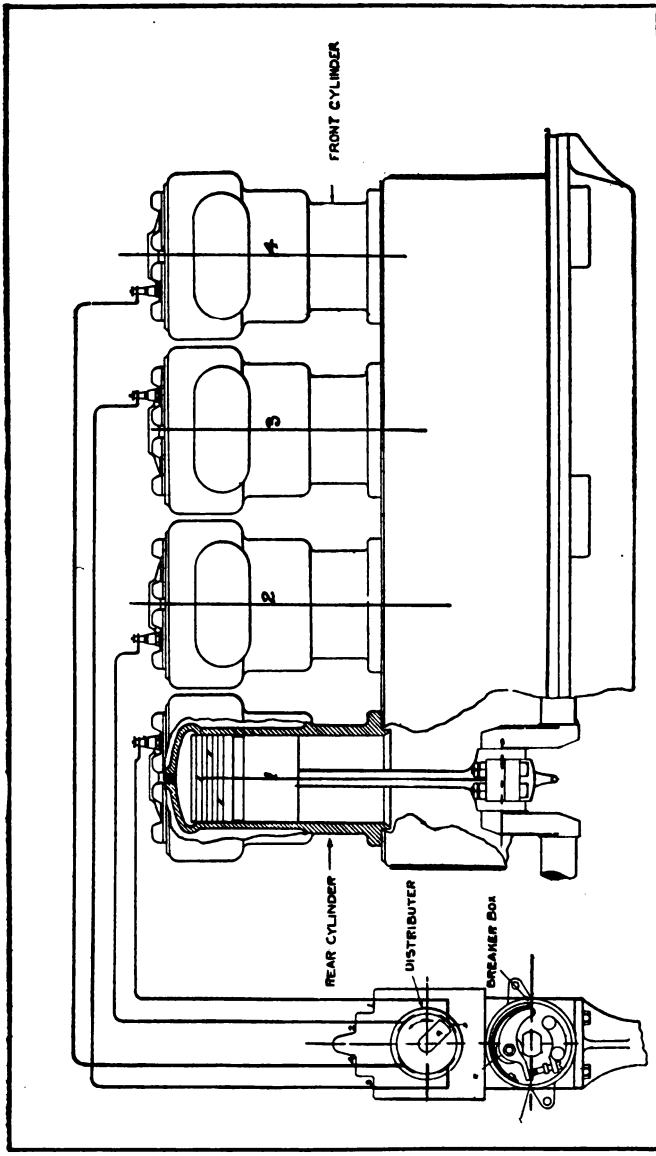

FIG. 78.—Simple Exterior Wiring of Four Cylinder High Tension Magneto Ignition System.

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the cylinder. As will be observed, one of the leads from the stationary primary winding goes to the ground while the other is led to the insulated contact point of the contact breaker. The condenser is interposed in the circuit so that it is in shunt or parallel connection with

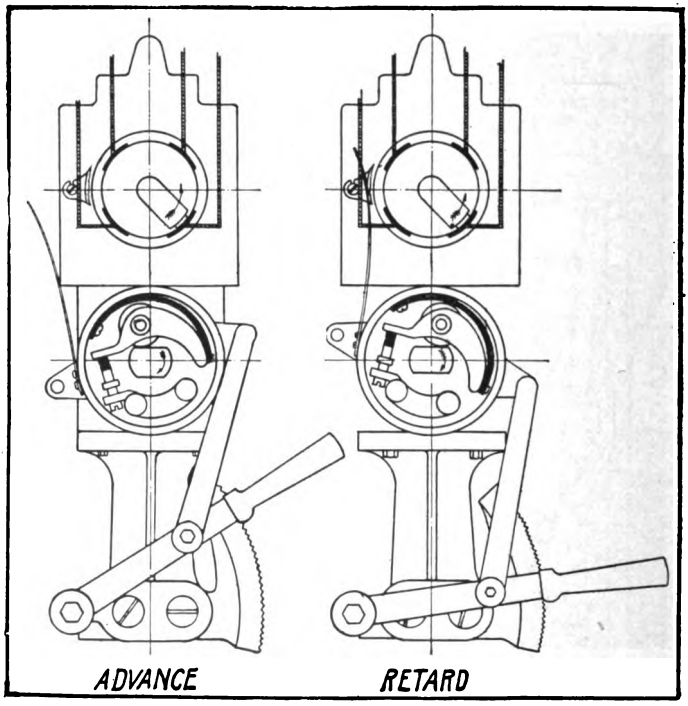

FIG. 79.—Illustration Showing Advance and Retard Positions of K. W. Magneto Breaker Box.

the contact points. As the two members comprising the condenser are insulated from each other the primary current cannot flow through this device. One of the high tension leads from the secondary winding is directed

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to the ground while the other goes to the revolving distributor brush of the distributing device. Four wires lead from the distributor to the various spark plugs of the engine.

When the points in the contact breaker are separated by the cam point a current of electricity is induced in the stationary winding because the inductor is at such a position between the pole pieces that a maximum current of electricity is being produced. The high tension current is distributed to the spark plug in the cylinder about to ignite, the spark plugs being brought into action progressively as the magneto distributor brush establishes contact with the insulated segments to which the plug wires are attached. The application of a typical true high tension magneto to a four cylinder gas tractor power plant is outlined at Fig. 78 and attention is directed to the simplicity of the external wiring.

Timing the Spark.—The contact breaker of either a magneto or battery ignition system should be arranged in some manner so that the time of sparking may be varied. In starting the engine by hand it is imperative that the spark be retarded, which means that it should occur later than the correct ignition point and only after the piston has started to go down again after it has reached the top of the compression stroke. When the spark takes place under these conditions the piston is always driven in the right direction and the engine cannot back fire. If the engine were started with the spark advanced the explosion would take place before the piston had reached the end of its compression stroke and it would be driven back in a direction opposite to that in which it should normally revolve. This will tend to knock the starting crank or flywheel out of the operators grasp and may result in a permanent injury

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to the wrist or arm if this is not removed out of the path of the incorrectly rotating starting handle.

While a late spark is desirable for starting and running an engine at low speed it is necessary to advance the spark when it is desired to operate the motor at a higher speed. To do this the timer case is usually rocked so the contact will be broken sooner between the points of the magneto contact breaker or established earlier in a timer for a battery ignition system. The positions of a magneto contact breaker when in advance and retard positions are clearly shown at Fig. 79. It will be seen that to obtain an advance spark the timer case is rocked so that the roller on the movable timer lever is brought into contact with the point of the cam sooner. In other words, to advance the time of the spark, the timer case is rocked in a direction opposite to that of rotation of the circuit breaking cam, whereas to retard the spark the contact breaker casing is oscillated in the same direction as that of cam rotation so the points of the contact breaker would be separated after the piston has started to go down on its explosion stroke.

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CHAPTER VI.

COOLING AND LUBRICATING THE POWER PLANT.

Reason for Cooling Engine—Thermo-syphon System—Forced Circulation Method—Oil Cooling Features—Parts of Cooling System—The Pump—The Cooling Fan—The Radiator—Why Engines are Oiled—Different Lubricating Mediums—Simple Gravity Oil Cup Method—Mechanical Oiling Systems—Constant Level Splash Systems.

Reason for Cooling Engine.—It is apparent that power is produced in an internal-combustion engine by a series of explosions in the cylinder. As the temperature of the explosion is over 2,000 deg. Fahr. in some cases, the rapid combustion and continued series of explosions would soon heat up the metal parts of the combustion chamber to such a point that they would show color unless cooling means were provided. Under these conditions it would be impossible to lubricate the cylinder because even the best quality of lubricating oil would be burnt. The piston would expand sufficiently to seize in the cylinder and the valves would warp so that they could no longer hold compression. Premature ignition of the charge would probably take place long before the engine was put out of commission by the distortion of the parts.

The fact that the ratio of engine efficiency is dependent upon the amount of useful work delivered by the heat generated from the explosion makes it important that

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the jackets be cooled to a point where the cylinder will not be robbed of too much heat. The losses through the water jacket of the average gas-tractor power plant are over 50 per cent of the total fuel efficiency. While it is very important that the engine should not get too hot, it is equally desirable that it is not cooled too much. The object of cylinder cooling is, therefore, to keep the heat of the cylinder metal below the danger point but at the same time keep the engine hot enough to obtain maximum power from the gas burnt.

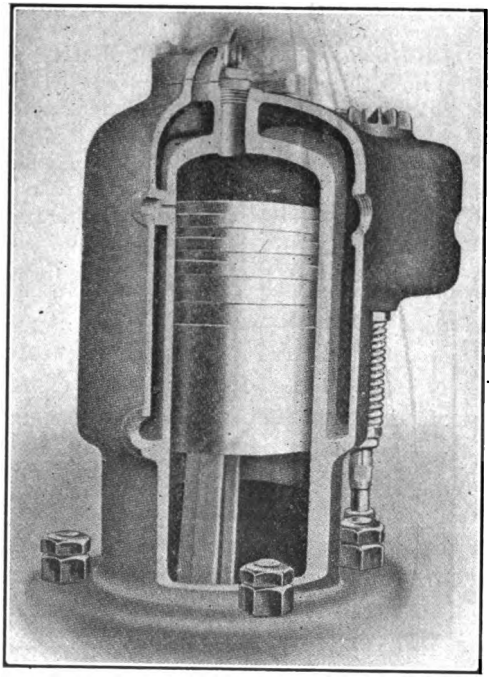

FIG. 80.—Part Sectional View of Water Jacketed Motor Cylinder.

Two general systems of cylinder cooling are in general use on farm engines, though the simpler air-cooled types are never found on gas tractors of regular manufacture, because air cooling is not considered practical for heavy-duty motors of the bore and stroke used as gas tractor power plants. Water

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cooling is the most popular method in all fields of endeavor in which the gasoline engine has been applied successfully with the exception of the motor cycle and aeroplane.

When a liquid is employed for cooling it is circulated through jackets which surround the cylinder castings, and when the excess heat is absorbed, the hot liquid (usually water but sometimes oil) is led to a cooler where the heat is abstracted from it by means of air currents. The cooled liquid is then taken from the cooler and again circulated around the cylinders of the motor. The sectional view of a typical cylinder at Fig. 80 shows the liberal space provided for water circulation.

Two methods of keeping the cooling liquid in motion are used. The simplest system is to utilize a natural principle that a hot liquid being lighter than a cold liquid will tend to rise to the top of the cylinder when it becomes heated, while cool water, which is heavier, takes its place at the bottom of the water jacket. The slightly more complicated system generally favored is to use a positive circulating pump of some form which is driven by the engine to keep the cooling liquid in circulation.

Thermo Syphon System.—Some eminent tractor designers contend that the rapid circulation of liquid obtained by means of a pump may cool the cylinders too much and the temperature of the engine may be reduced to a point where its efficiency will be somewhat lower than if the engine were allowed to run hotter. For this reason many designers, especially in the automobile field, use the natural method of water circulation. The cooling liquid is applied to the cylinder jackets below the boiling point and the water issues from the top of the jacket after it has absorbed enough heat to raise it just about to the boiling point. The simplicity of

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the thermo syphon system of cooling is clearly outlined at Fig. 81. With this system of cooling it is necessary to use more liquid than with pump circulated systems and the water jackets of the cylinders, as well as the water spaces in the radiator and the water inlet and discharge manifolds, must have greater capacity and be free

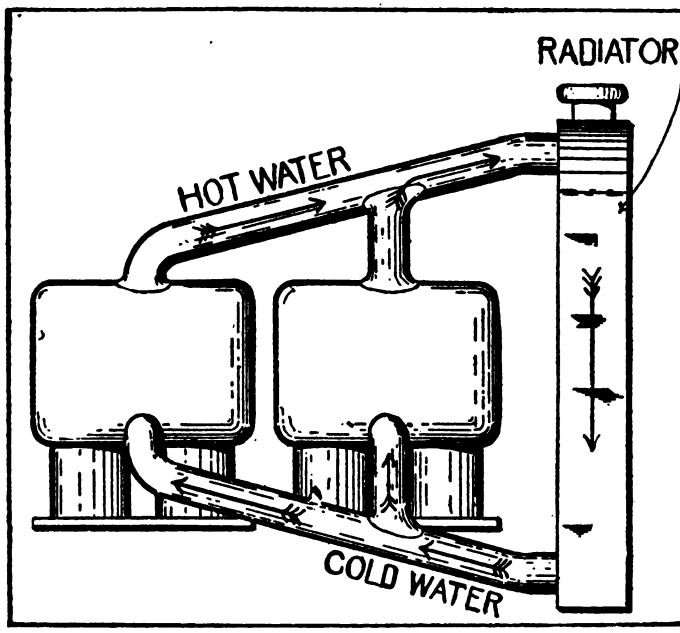

FIG. 81.—Action of Simple Thermo-Syphon Cooling System Outlined.

from sharp corners that might impede the flow of liquid. The direction of flow of the currents of water are clearly depicted and there should be no difficulty in understanding the action of this form of cooling system.

The Forced Circulation Method.—A system of cooling in which a pump is depended on to promote cir-

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culation of water is shown at Fig. 82. The radiator is generally carried at the front end of the tractor frame and serves as a combined water tank and cooler in most cases. It is usually composed of upper and lower water tanks, joined together by a series of pipes, which may be round and provided with a number of corrugated flanges to radiate the heat, or which may be flat in order to have the water pass through in thin sheets and cool more

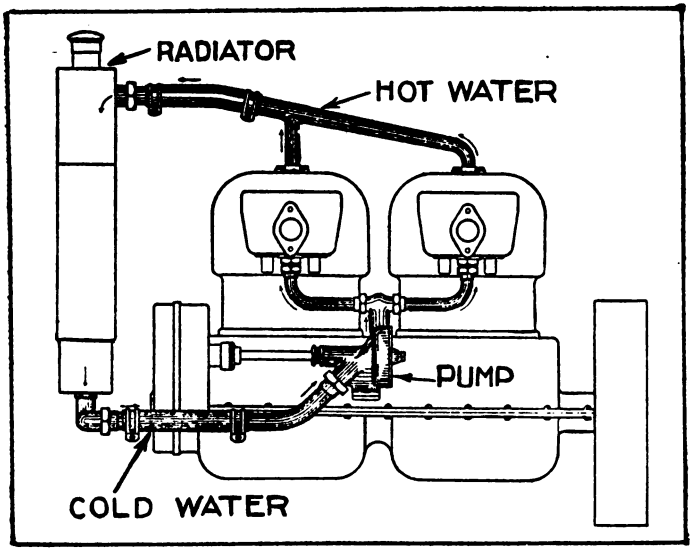

FIG. 82.—Forced Water Circulation Method of Cooling Engine Cylinders.

easily. The cold water which settles at the bottom of the cooler is drawn from the lower part of the radiator by a gear-driven pump and is forced through a manifold to the water jackets surrounding the exhaust valve chamber of the cylinder. As the water becomes heated it passes out of the top of the water jacket into the

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upper portion of the radiator, but as a general rule the rate of circulation is dependent upon the power of the pump rather than the degree of temperature of the water. On account of the more rapid flow of liquid, the radiator and piping may be of less capacity than when the simple thermo-syphon is employed.

Oil-cooling Features.—Some tractor manufacturers use oil as a cooling medium instead of water because this material is claimed to be more satisfactory in cold weather. Water will freeze unless it is mixed with some anti-freezing solution such as wood alcohol, glycerine mixtures and calcium chloride solutions. Many tractor operators do not care to use anti-freezing compounds either because of expense or on account of a chemical action and salt deposit which is present when the cheaper alkaline solutions are used. If pure water is used in the cylinder jacket as a cooling medium, it must be drained from the cylinder and cooler as soon as the engine is stopped if the temperature is below 32 deg. Fahr.

The Hart-Parr oil-cooling system is outlined at Fig. 83. This is claimed to have been in successful operation for a number of years without any question ever having been raised regarding its efficiency. The system is very similar in action to that of the conventional forced circulation water-cooling group, except that the radiator and cylinder jackets are filled with a special cooling oil which takes the place of the usual water supply. As the oil never boils and as there is no waste because of evaporation, the original oil supply furnished with the tractor should last as long as the engine itself. Any loss due to leakage may be cheaply renewed.

The radiator is constructed of numerous thin corrugated sections, with a conical hood and short stack at the top. The exhaust is piped into the hood and the exhaust

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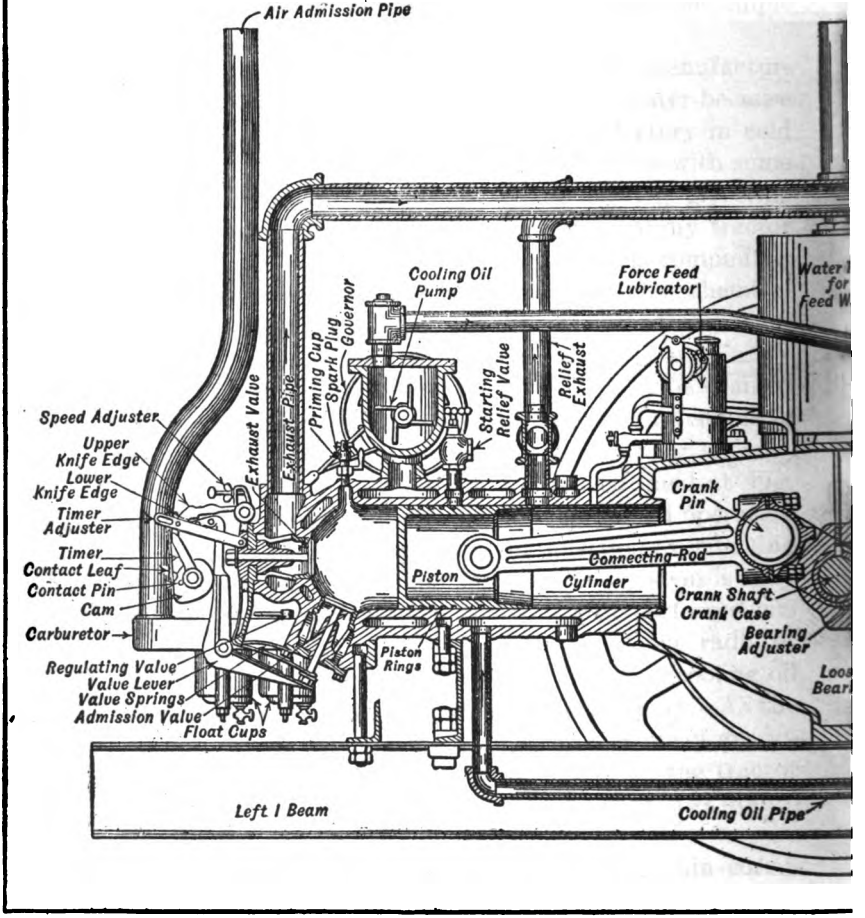

Fig. 83.—Sectional View of Hart-Parr Horiz

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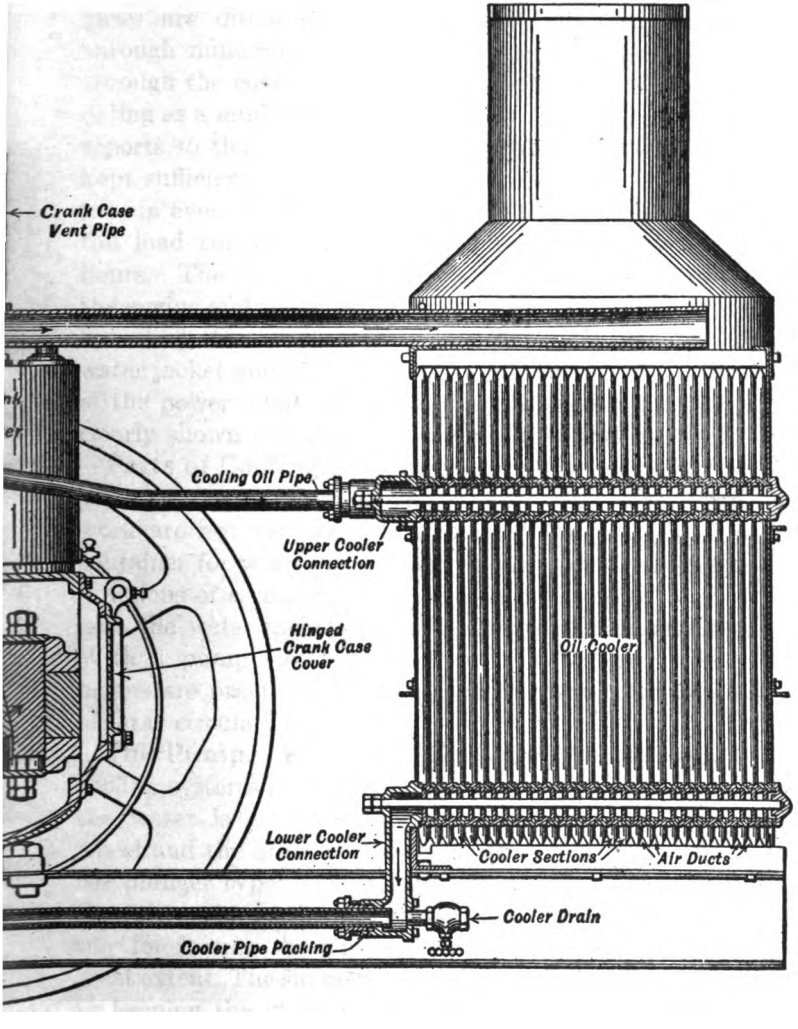

al Power Plant Showing Oil Cooling Method.

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gases are discharged upward from the exhaust pipe through numerous holes, this causing a powerful draft through the cooler because of an ejector action and also acting as a muffler for the exhaust by softening the sharp reports so that they are not annoying. The cylinder is kept sufficiently cool for successful operation of the engine in even the hottest weather, or when worked under full load continuously for any number of consecutive hours. The circulating pump is mounted at the top of the engine and is driven by positive means. The method by which the various pipes are joined to the pump, water jacket and cooler, and the construction of all parts of the power plant, as well as the cooling system, are so clearly shown that further description is unnecessary.

Parts of Cooling Systems.—It will be seen that the parts of the simplest cooling system used in practical work are not very complicated, consisting simply of a container for water, which may or may not combine the functions of a cooler as well, and suitable piping to connect the water jackets of the motor to the water tank. With a pump circulation system this and its driving means are practically the only additions to the simpler natural circulation method.

The Pump.—Pumps used in connection with water-cooling systems are of two general forms, those in which the water is circulated by revolving gears or paddle wheel and the other and more positive form which is of the plunger type. The rotary pumps are more popular than the reciprocating members because there is no necessity for forcing the water along under pressure to any great extent. The simpler forms which promote circulation by keeping the water in motion are all that are needed. The pump is usually driven by positive means, oftentimes by gearing direct from the motor crank shaft or cam shaft.

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The principal parts of a simple centrifugal pump are clearly outlined at Fig. 84. The impeller or paddle-wheel member is secured to the center of the shaft which is supported at each end by bearings in the members comprising the pump casing. This is made in two parts, usually divided vertically along the center line of the impeller wheel. The halves of the pump casing are faced

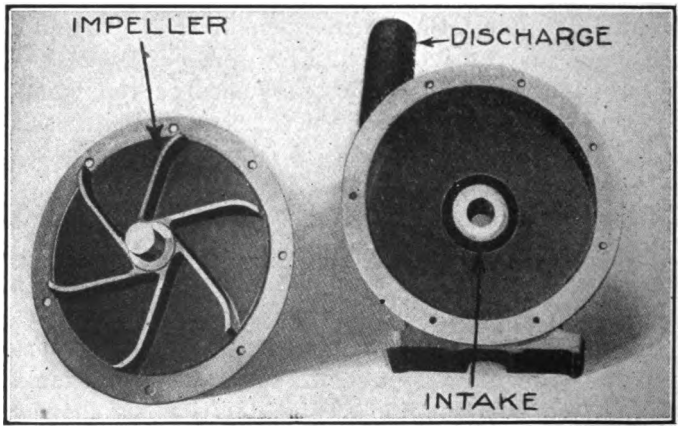

FIG. 84.—Simple Form of Centrifugal Pump for Circulating Cooling Liquid.

off so that the joint matches well and a water-tight point of junction is insured by a packing between the halves held positively in place by means of through bolts holding the two halves of the casing together. To obtain proper service from a centrifugal pump the vanes of the impeller wheel should be a fair fit in the pump casing. Other forms of rotary pumps in which a pair of gears or an eccentrically placed revolving element are incorporated are also used, but not so widely as the simple form of centrifugal pump described.

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The Cooling Fan.—As gas tractors are comparatively slow-moving machines, one cannot depend on the circulation of air through the radiator tubes by the natural draft, as is the case in many automobiles traveling at high speed. This condition is met in two ways, the simplest expedient being to provide a water container of large capacity, having a large amount of radi-

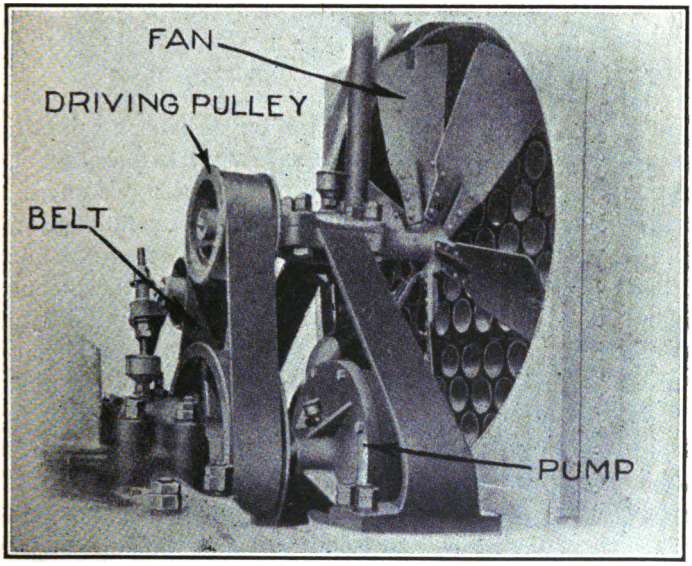

FIG. 85.—Cooling Fan Necessary Unless Large Volume of Water is Carried.

ating surface. In the better designed tractors, the lack of natural draft is compensated for by using a positively driven four or six-blade fan back of the radiator, the blades being inclined at such an angle that air is drawn in through the radiator spaces.

These fans, one of which is shown at Fig. 85, are driven

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by leather belts running over flanged pullies, as a rule, though sometimes more positive gear-driving means are employed. When a belt is used for driving the fan some method of adjustment by which the belt tension may be maintained to the proper degree to insure positive drive is provided. With gearing this is not necessary, though it is advisable to provide some form of friction member between the fan hub and the positive driving means to prevent throwing off a fan blade should the engine action become "jerky" and fan drive irregular.

When a fan is employed the positive circulation of air insured by its use enables the tractor designer to obtain adequate cooling with much less water than would be needed if the fan were not used. The argument offered against its use that it introduces an item of complication in the tractor mechanism is true to a limited extent but the construction of the fan is so simple and the means employed in driving it so apparent that it is not likely to cause any trouble to even the inexperienced gas tractioneer.

The Radiator.—The simplest form of radiator is shown at Fig. 86. This is really a combined water tank and cooler. The lower portion is a galvanized iron tank which carries a couple of headers or supporting brackets at each end to which corrugated pieces of sheet metal resembling to some extent the metal face of a washboard are attached. At the top of these corrugated, inclined members are the water discharge pipes from the top of the water jacket of the engine. Under the influence of the pump the cold water pumped into the bottom of the water jacket is constantly forcing the hot water through the pipes of the cooling system to the perforated pipes at the top of the cooler. The large number of small holes insures that the same number of streams of water will be

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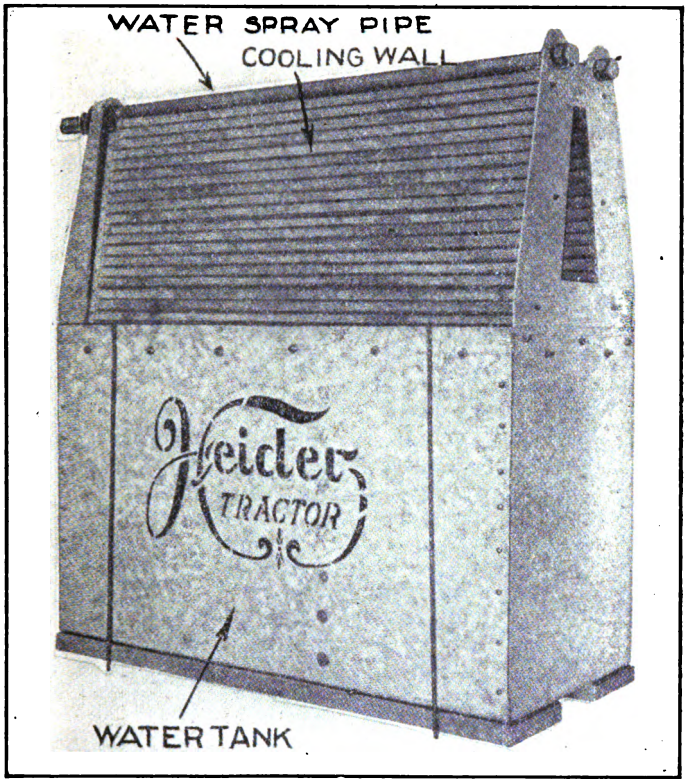

FIG. 86.—Simple Combined Cooler and Water Container.

discharged which trickle down the corrugated surface of sheet metal. As this is cooled by exposing a large surface to the air and as the water is divided, in a series of very thin streams from which the heat is readily abstracted when it reaches the bottom or tank portion, it has become cooled enough so it can be forced back into the water jacket of the engine again.

A much more efficient type of cooler is shown at Fig.

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86-A. This is composed of an upper and lower header, which are joined together by a number of readily detachable units, each comprising four pipes around which a large number of light sheet metal flanges are attached to

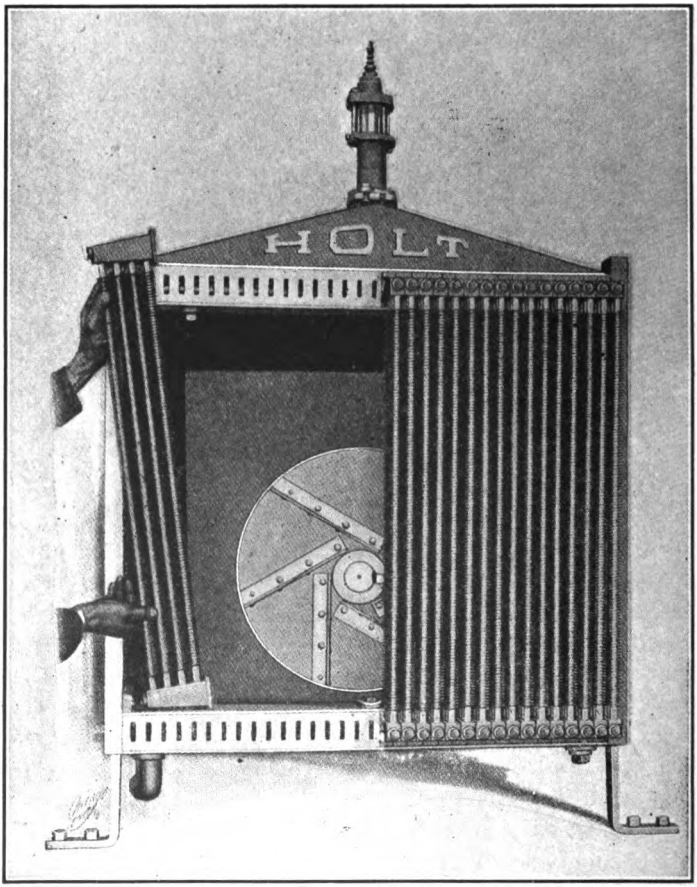

FIG. 86A.—Radiator Used on Holt Tractors Has Detachable Cooling Sections.

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increase the effective area of metal exposed to the air. This type of radiator has the advantage of permitting the ready removal of any one of the sections should it become damaged in any way without putting the cooler out of commission. All that is necessary is to stop up the holes by means of a plate and packing. As the water in descending from the top container to the lower portion of the radiator must pass through a large number of tubes and as a positive air current is induced by means of a power-driven fan, placed in back of them, very satisfactory cooling is obtained without the necessity of carrying a large amount of water, as is needed with the simpler types of radiator shown at Fig. 86.

Other radiators are composed of rectangular section tanks or cylindrical containers through which a large number of light steel or copper tubes pass in just the same manner as the tubes of a fire tube boiler. The cooling air currents are drawn through the tubes to cool the mass of water surrounding them, which is the reverse to the process employed in a boiler where hot gases are passed through the tubes to heat the water. When this form of radiator is used it is necessary to supply a fan to produce a positive air draft and insure adequate cooling without the use of excessively large water capacity.

Why Engines Are Oiled.—All bearing surfaces, no matter how smooth they appear to be to the naked eye, have minute projections, and when examined under a microscope the surface of even a finely finished bearing appears rough. If bearings were run without oil, the projections on the shaft and on the bushing or box in which the shaft revolves would tend to interlock and a great amount of friction would result. This would mean that much of the power developed by the engine would be utilized in overcoming friction. Without some means

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of minimizing this loss considerable heat would be generated if the bearings were run dry and the result would be that the overheated bearings would soon depreciate and would give signs of distress long before they failed by becoming firmly burned together.

The reason that a lubricant is supplied to bearing points will be readily understood if one considers that the close-fitting surfaces of the shaft and bushings are separated by means of an elastic substance which not only fills up the minute depressions, thus acting as a cushion, but which absorbs the heat generated by friction as well. In properly lubricated bearings the oil takes all the wear that would otherwise come on the metallic bearings. The grade of oil and amount to use depend entirely on the bearing points where it is to be applied. An oil that would be entirely suitable for lubricating the interior surfaces of the gas-engine cylinder would not be suitable for bearings in some cases if these were subjected to heavy pressures. At the other hand the semi-fluid oil or grease which cushions the teeth of the driving gearing so well could not be used in the cylinders of the engine.

When used for gas-engine lubrication an oil must be capable of withstanding considerable heat in order that it will not be evaporated or decomposed by the hot metal of the cylinder. The oil used for cylinders or bearings should have a low cold test, i. e., it should not thicken up at low temperatures so that it will not flow freely. All authorities contend that lubricants must be free from acid which will corrode the metal surfaces to which the oil is applied. A lubricant must have sufficient body to prevent metallic contact of the parts to which it is applied, and between which it is depended upon to maintain a resilient film. It should not have

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too high a body or too much viscosity because a lubricant that is too thick will have considerable friction in itself and will not flow readily between bearing surfaces.

If the lubricant is to be used in slow-moving, high-capacity bearings, such as those of a rear axle, or in gearing where great cushioning qualities are desired in addition to positive lubrication, it must have a heavy body and the semi-solid greases are the best materials to use for this purpose. The grease or oil should also be free from injurious adulterants of either vegetable or animal origin, because these invariably contain fatty acids that will decompose and attack metal surfaces or gums which will coagulate or oxidize by exposure to air and retard the action of the bearings. The best lubricants for tractor use are derived from a crude petroleum base with the exception of commonly employed graphite which is a form of pure carbon that is a good lubricating medium.

Different Lubricating Mediums.—Oils of organic origin, such as those obtained from animal fats or vegetable substances, will absorb oxygen from the atmosphere which may cause them to become rancid. As a rule these oils have a very poor cold test because they solidify at comparatively high temperatures. Their flashing point and fire test are also so low that they are not suitable at points where considerable heat exists, such as the interior of a gas engine. The only oil that is used to any extent in lubricating gas engines that is not derived from a petroleum base is castor oil which is obtained by pressing the seeds of the castor plant. This has been used on high-speed racing automobile engines and on aeroplane power plants, where it is practically pushed right up past the piston and out of the combustion chamber with the exhaust gases so that fresh oil must be supplied all

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the time to replace that ejected from the engine. Obviously this method of oiling would not be considered economical and would not be suitable on either business or pleasure automobiles or gas tractors.

Among the solid substances that have been used for lubrication to some extent may be mentioned tallow, which is obtained from the fat of certain animals, such as cattle and sheep; graphite, which is a natural product, and soapstone, which is also of mineral derivation. Tallow is usually employed as a filler for some of the greases used in slow-speed bearings or in transmission gearing but should never be utilized at points where it will be exposed to much heat. Graphite is obtained commercially in two forms, the best known being flake graphite, where it exists in the form of small scales or minute sheets, and the deflocculated form, where the graphite has been ground or otherwise divided into a dust. It is usually mixed with oil of high viscosity and used in connection with lubrication of running gear parts, though it has been mixed with cylinder oil and applied to engine lubrication with some degree of success. Graphite is not affected by heat or cold, acids or alkali, and has a strong attraction for metal surfaces. It remains in place better than an oil and as it mixes readily with oils and greases their efficiency for many applications is increased by its use.

The oil that is to be used in the gasoline engine must be of high quality and for that reason the best grades are distilled in a vacuum so the light distillates will be separated at a much lower temperature than ordinary distilling practice permits. When distilled at the lower heat the petroleum is not so apt to decompose and deposit free carbon. A suitable lubricant for gas-engine cylinders has a vaporizing point at about 200 deg. Fahr.,

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a flash point of 430 deg. Fahr., and a fire test of about 600 deg. Fahr. Cylinder oil is one lubricant that must be purchased very carefully. A point to remember is that the best quality oils, which are the most efficient, can only be obtained by paying well for them. The few cents saved in using a cheap oil is not of much moment when compared to the repair bill that may accrue from its use. The cheap oil will not only deposit carbon very freely in the cylinder heads but is liable to gum up the piston rings and valves and detract much from the smooth operation and power capacity of the motor. Bearings lubricated with it will also have more friction and consume more power than when good oils are employed.

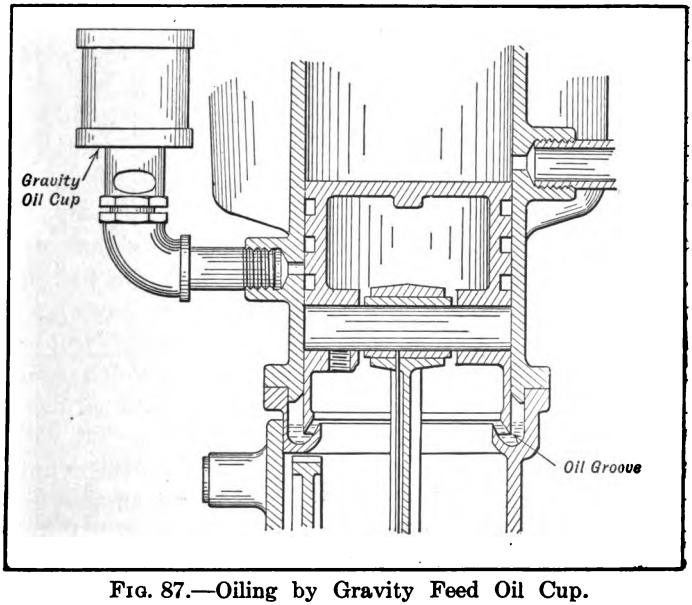

FIG. 87.—Oiling by Gravity Feed Oil Cup.

Simple Gravity Oil Cup Method.—One of the simplest devices for supplying lubricant to the gas-

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engine cylinder is the sight-feed oil cup, which has been widely employed in general steam engineering practice for some time. This consists of an oil container usually composed of metal flanges at the top and bottom between which a glass body, which permits one to see the height of oil in the container, is fastened. A central supply tube terminates in a small compartment under the main body which also has a glass wall so that the drops of oil may be seen dripping from the end of the supply tube. The amount of oil supplied is regulated by an adjustable needle valve which makes it possible to compensate for differences in temperature and viscosity of the oil and keep the supply to the amount needed.

The application of a sight-feed oil cup is outlined at Fig. 87 though this shows it attached to the wall of a two-cycle engine cylinder. The same method of lubrication would apply to a four-cycle type as well. It will be noticed that the oil is supplied to the cylinder walls at such a point so that when the piston is at the bottom of its stroke the oil supply will be to a point a little above the wrist-pin. As the piston moves up the oil collects in the chamber back of the supply pipe until the hollow wrist-pin registers with the opening. The oil flows into the wrist-pin and from this point to the lower crankshaft bearing through a small copper tube which connects the upper and lower connecting-rod bearings. When the piston reaches the top of its stroke oil will flow into the annular oil chamber at the base of the cylinder, and as the bottom of the piston dips into this oil groove at the end of every down stroke, enough oil will be carried up to insure adequate lubrication of the cylinder walls.

The sight-feed oiler needs continual attention, so most of the modern tractors are provided with mechanical

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lubrication systems. When a positively driven oil pump is used one is sure that oil will be delivered to all bearing points, whereas in the sight-feed gravity oiler, if the oil thickens up or if the opening in the supply pipe becomes clogged with a small piece of lint or bit of wax, the oil feed stops and unless there happens to be a considerable amount in the crank case the engine may be injured by the failure of continuous oil supply.

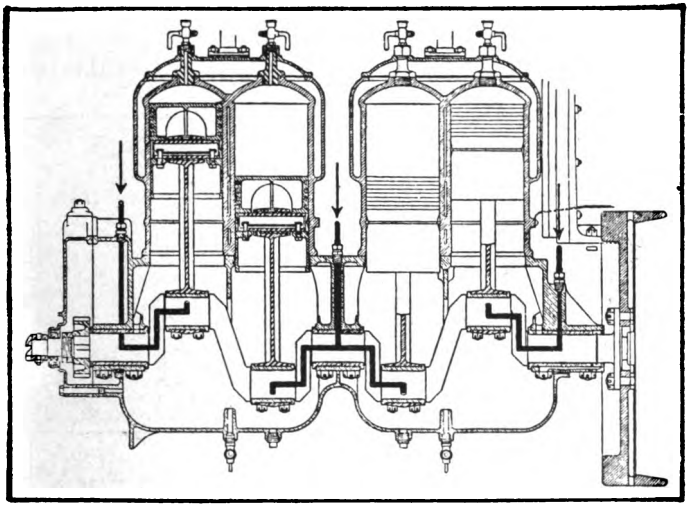

FIG. 88.—Sectional View of Four Cylinder Engine Showing Passages for Oil Distribution in Crankshaft.

Mechanical Oiling Systems.—The simplest possible form of a mechanical oiling system and one that gives very good results in practice is called the constant level splash system. The other method, which calls for the use of a multiple positive drive oil pump, is also used to some extent. At Fig. 88 the cross-sectional view of a four-cylinder four-cycle power plant clearly shows the

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application of a three-lead positive oil-pump system. The crank shaft is provided with passages indicated by the heavy lines. An oil lead goes to each main bearing, and after it has served its purpose there the oil is taken through the passage in the crank shaft and led to the four connecting rod bearings, from which it is thrown around the interior of the motor by centrifugal force from the rapidly revolving crank shaft. The interior of the engine is filled with a continual mist or spray of oil and all parts are thoroughly lubricated. The excess oil drops into the crank case, which it fills to the level

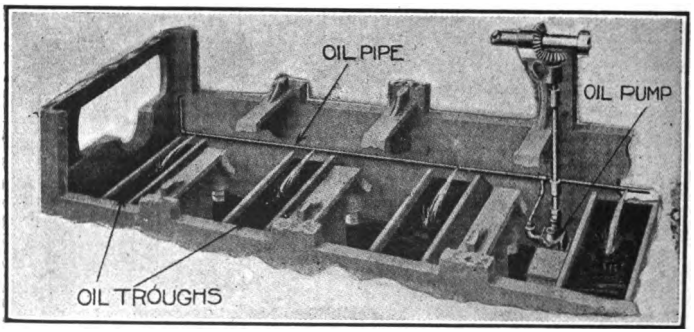

FIG. 89.—Method of Supplying Oil Troughs of Holt Tractor Motor Crankcase.

determined by the height of the standpipes in each crankcase compartment. This height is just enough so the lower portions of the connecting-rod caps just skim over its surface and pick up some of the lubricant and by splashing it around the interior assist materially in its distribution. The oil is supplied to the main bearings under considerable pressure and must reach these bearing points. From that point the distribution is automatic through the passage drilled in the crank shaft

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and the splashing action of the connecting rods as they dip into the oil pools in the compartments at the lower portion of the crank case.

The lubricating system outlined at Fig. 89 shows clearly the method of oil distribution by means of a connecting rod. The oil pump, which is driven by means of bevel gearing from the motor cam shaft, draws oil from the lower portion of the crank case and delivers it

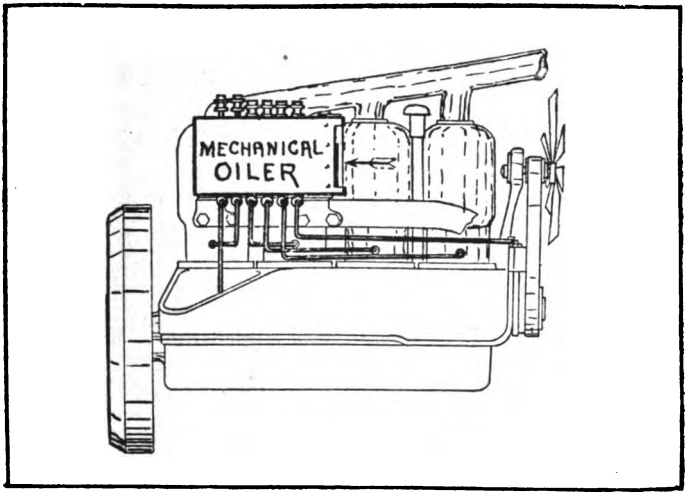

FIG. 90.—Mechanical Oiler Attached to Motor. Note Leads to Cylinders and Timing Gear Case.

to a manifold pipe which supplies four troughs extending across the crank case and into which the connecting rods dip as the crank shaft revolves. This is really a constant level splash system. All the interior parts of the motor are lubricated by the oil spray produced by the rapidly revolving connecting rod big ends.

The application of an individual lead-system mechanical oiler to a four-cylinder engine is clearly shown at

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Fig. 90. It will be observed that six pipes lead from the bottom of this device, four of which go directly to the cylinders while one goes to the timing-gear case at the front end of the motor and the remaining one directly to the crank-case interior. The device is driven by gearing which is not shown in the illustration. The interior of the mechanical oiler showing a sectional view taken

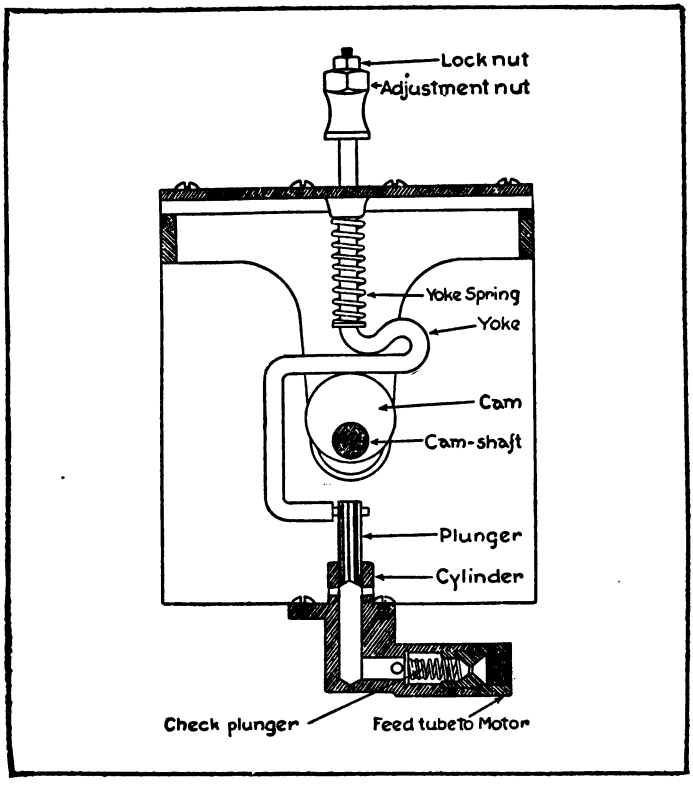

FIG. 91.—Sectional View of Simple Mechanical Lubricator Showing Parts.

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through one of the pumps is depicted at Fig. 91. The pump plunger is operated by means of a metal yoke which rides on the surface of the operating cam. The yoke is kept seated against the cam periphery by means of the yoke spring, and when the parts are in the position shown oil can flow into the pump cylinder through the two small holes immediately under the pump plunger. As the oiler cam shaft rotates, carrying the cam with it, the yoke is forced down by means of the yoke spring and the pump plunger is pushed into the cylinder with considerable force, this displacing the oil from the cylinder and forcing it past the check plunger (which opens because of the oil pressure) through the feed tube attached to the motor by a conductor of flexible copper tubing.

The amount of oil is regulated by an adjustment nut which may be screwed up or down on the stem of the yoke which projects through the cover of the device and which will thus limit the effective stroke of the pump plunger. Obviously, the greater the stroke the more oil will be supplied at each revolution of the cam shaft and each downward movement of the yoke to which the pump plunger is attached. The number of pumps varies with the number of bearings that are to be supplied, and as a general rule one pump is allowed for each bearing point. Those that require large amounts of oil are arranged so the full stroke of the pump plunger is utilized, while the leads that do not require much oil are joined to pumps adjusted with a very short stroke, so the quantity of oil displaced by the plunger at each revolution of the cam shaft is relatively small. The entire interior of the device that is not occupied by machinery serves as a container for oil and a sight-feed gauge glass set into one corner of the lubricator body indicates the amount of oil available at all times.

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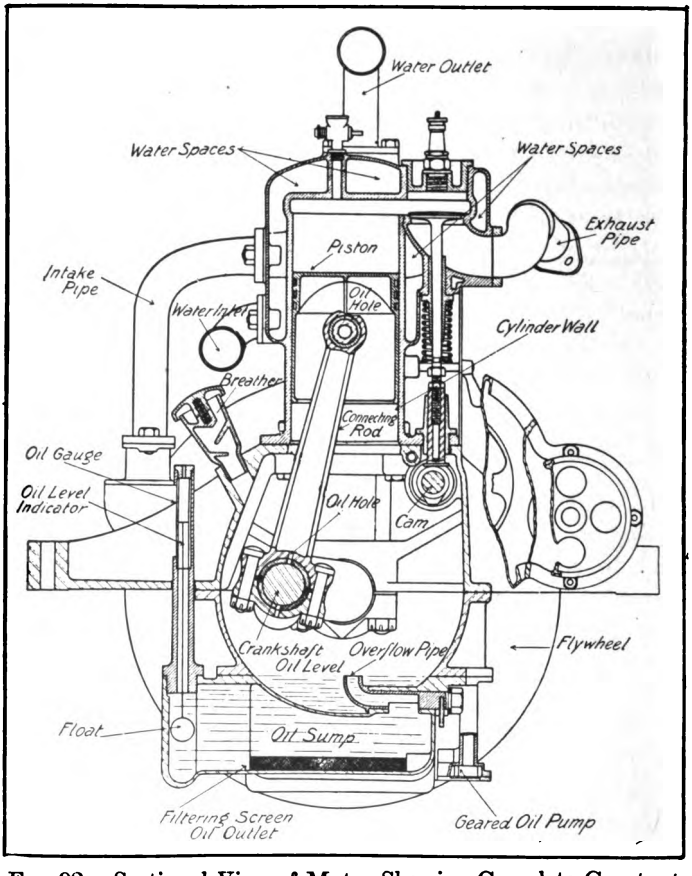

FIG. 92.—Sectional View of Motor Showing Complete Constant Level Splash Lubricating System.

Constant Level Splash System.—The constant level splash system has become very popular on motor cars and is also widely used on gas-tractor power plants that are based on automobile engineering practice. The application of a typical system of this kind is shown at

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Fig. 92, and in view of the clear manner in which the various parts are outlined, very little explanation is necessary. The lubricant is carried in a sump or oil container at the bottom of the crank case which may be filled through the breather pipe conveniently arranged at the top of the crank case and having a removable cap to permit the introduction of lubricant to the crank case interior. The oil level in the sump is shown by means of an oil gauge carried by a small float which falls when the oil level decreases to the point where the supply in the crank case must be renewed.

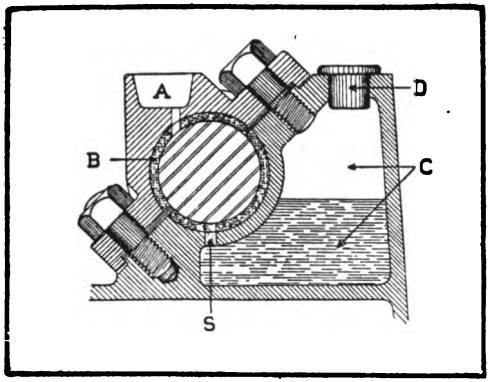

FIG. 93.—Method of Lubricating Main Bearings From Oil Reservoirs Integral With Crankcase.

The oil is taken from the sump by means of a geared oil pump and is discharged into the crank case. It fills the crank case to the level determined by the overflow pipe, the position of which may be varied as desired by rocking it in its bearings. The oil level is usually of such height that will permit the splasher or oil scoop on the bottom cap of the connecting rod to dip into it. With this system all of the interior mechanism is lubricated

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by means of the oil mist produced by the rapidly-revolving crank shaft. All excess oil supplied flows back into the sump through the overflow pipe and is filtered through the screen at the oil outlet before it is again supplied to the crank-case interior. In this manner only clean oil is supplied and one filling of lubricant will last for a run of three or four hundred miles. At the end of this period all the old oil is cleared out of the crank case and oil sump through a suitable drain cock and the supply is replenished with new, unused oil.

In the systems previously outlined the main bearings are lubricated either by oil supplied by individual leads or by a mist which is present in the crank case all times that the engine is in operation. Another method of lubricating main bearings, which has been applied to stationary engines with some degree of success and which is also suitable for tractor power plants where the cylinder is oiled from a sight-feed oiler, is shown at Fig. 93. The main-bearing pedestal is cored out, as shown at **C**, this forming an oil chamber which can be filled through the plug **D**. As the oil level at **C** is higher than the bottom of the bearing oil will be supplied continuously through the passageway **S** which provides communication between the shaft and the oil container. The brasses **B** are thus covered with a film of oil which is maintained automatically as long as the oil level in chamber **C** is higher than the bottom of the bearing **B**.

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CHAPTER VII.

FUNCTIONS AND CONSTRUCTION OF CLUTCH, GEAR-SET AND DIFFERENTIAL.

Why Clutch is Needed—Action of Simple Clutch Described—Some Typical Tractor Clutches—Friction Disc and Roll Clutches—Why Reversing Mechanism is Needed—Typical Reversing Mechanism—Why Speed Changing is Necessary—Action of Simple Change Speed Gears Outlined—The Differential Gear and Its Use.

Why Clutch Is Needed.—One of the important members of the power-transmission system of the gas tractor is the friction clutch employed to connect the power plant to the rear wheels or to break the driving connection between the power generating and traction members when desired. A clutch is absolutely necessary on a gas tractor, though on a steam tractor it is not customary to provide a clutch between the engine and the driving wheels, though in some cases this device is furnished on the steam-power plant as well. Steam engines are capable of delivering power considerably in excess of their rating, and as the steam which furnishes the power is stored under pressure in the boiler it is possible to start the steam engine under load. The amount of power delivered from a steam engine may be varied by regulating the quantity and pressure of the steam going to the cylinders and a simple throttle-valve lever is all that is needed to control the speed of the steam tractor and to start or interrupt the drive when desired.

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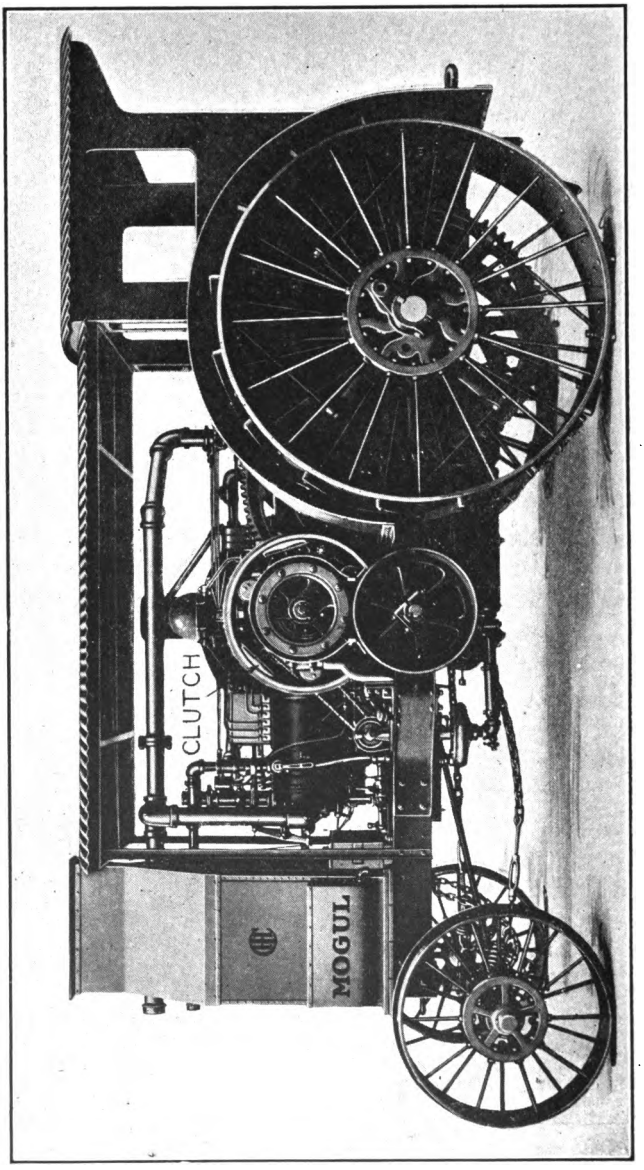

FIG. 94.—Side View of I. H. C. Mogul Tractor, Showing Location of Clutch.

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When a gasoline engine is used as a power plant, conditions are radically different. It is not possible to start any explosion motor under load, because the power is obtained by the combustion of fuel directly in the cylinders and there is no external source of energy to draw from, as is the case with the steam engine. The power produced by a gasoline engine depends upon the rapidity with which the explosions follow each other, and unless the engine is turning over at a certain speed, it is not delivering its full power. It has been demonstrated that a certain cycle of operations is necessary to secure gasoline-engine action. For example, consider the case of a single-cylinder engine, started under load. If there was a charge of gas already in the cylinder and this was exploded, the piston might make one stroke, but as there would be no further energy supplied, the crank shaft would come to a stop on account of the resistance. It will be apparent, therefore, that the gasoline engine must revolve free of load in order to start it. The piston must go through the functions of drawing in a charge of gas, compressing it, and then firing it before any power is produced. Even after the engine is started, it must attain a certain speed to supply the power needed to overcome the resistance that tends to prevent motion of the tractor, before it can be used in driving it.

It is very desirable that the gas tractor be started or stopped independently of the engine. On a steam tractor it is possible to start it as soon as steam is admitted to the cylinder from the boiler, but with a gasoline engine it is customary, and in fact necessary, to interpose some clutch mechanism between the engine and driving wheels, which will make it possible to couple the power plant to the traction members and disconnect it at will. The friction clutch is the simplest method of

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accomplishing this result. This consists merely of a locking member, which is capable of joining the driving shaft to the crank shaft of the engine when desired. The location of a typical clutch is clearly shown at Fig. 94, as applied to a gas tractor. The clutch is usually operated by a hand lever and as a rule the leverage is proportioned so that but little effort is needed on the part of the operator to apply or release the power.

Action of Simple Clutch Described.—Clutches that utilize the driving properties of frictional adhesion have proven to be the most satisfactory in practical application. The most important requirement is that the clutch be capable of transmitting the entire power of the engine to which it is fitted without any loss due to slipping. The clutch should also take hold gradually because any "grabbing" will produce stresses that may seriously injure the mechanism. It is imperative that the two portions of a clutch member disengage positively when the clutch is released so that there will be no dragging or rotation of parts. Other factors to be considered are to provide as much friction surface as possible, to have the clutch members placed in an accessible position, and to provide adjustment so a certain amount of wear can be taken up.

A simple friction clutch such as used in transmitting power from one shaft to another is shown at Fig. 95, which illustrates all the important parts of the mechanism. The clutch ring **K** is about half the diameter of the pulley and is attached to the arms or spokes by casting integral in some cases and by making it a separate bolted member in others. The inner jaws **G** on each arm are forced outward and the outer jaws **H** inward by means of the toggle levers **SU** which operate upon the levers **E**. This lever has its fulcrum between its points

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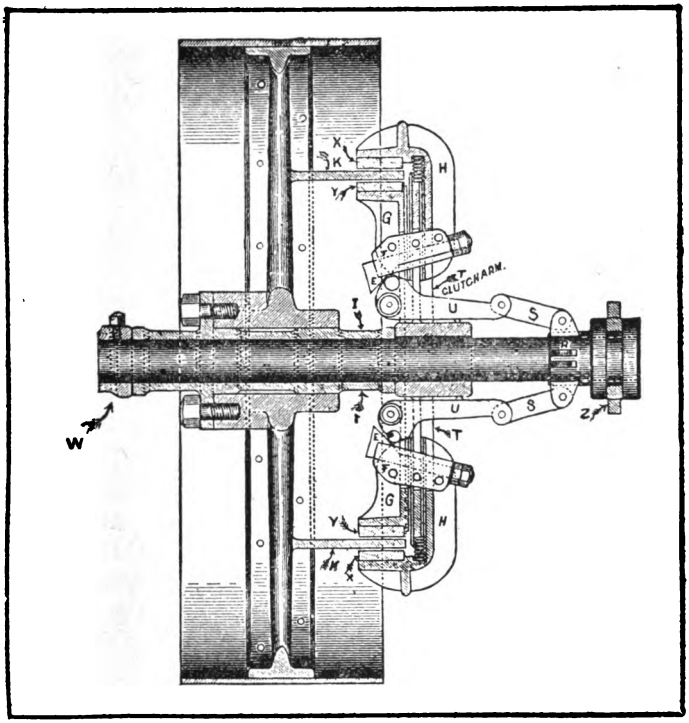

FIG. 95.—Sectional View of Simple Clutch, Showing Principal Parts.

of connection with friction members **G** and **H** and is operated by means of a inclined cam member, which is lifted by a roller or contact member carried at the end of the bell-crank lever **U**. As will be evident the friction members **G** act against the inner periphery of the cast-iron clutch ring **K** while the friction members **H** act against the outer periphery of the same member. Four to six sets of friction members are provided, and when the bell crank **U** is operated by the toggle **S**, the end

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of the rocker lever **F** which carries the cam **E** is raised. This pushes the shoe **G** up and pulls down the shoe **H**. The shoe **H** is provided with a friction block of well-seasoned maple **X** and the shoe **G** is provided with a friction member of the same material at **Y**.

The belt pulley revolves on a bushing which turns freely on the driving shaft when the clutch is disconnected. The spider that carries the clutch members **G** and **H** and their actuating mechanism is keyed to the shaft and revolves with it. To engage the clutch the collar **Z** is pushed toward the pulley, this clamping the ring attached to the pulley firmly between the driving shoes which are revolving with the shaft. When the pulley is locked to the revolving-clutch member it must turn with it and at the same speed because the lock is positive. If the friction blocks slip considerable power will be lost in transmission. To release the clutch the collar **Z** is pulled away from the pulley and the jaws **G** and **H** spread apart, allowing the cast-iron driving-ring **K** to revolve freely between them. In this way it will be seen that motion may be imparted to a stationary shaft by means of a revolving pulley or *vice versa*.

Some Typical Tractor Clutches.—A very efficient type of clutch used on the Holt tractors is shown at Fig. 96. This is a three-plate type and the cast-iron ring which acts as a driving member is clamped between the two driven members in much the same manner as previously explained. The engine fly-wheel carries a clutch casing in which a floating driving plate is keyed. This plate must turn with the fly-wheel but may move back and forth on its keys. The engine crank shaft terminates in the hub of the fly-wheel while the drive is taken up by an independent shaft which runs into a telescopic bearing of the plain bushing type carried in the hub of

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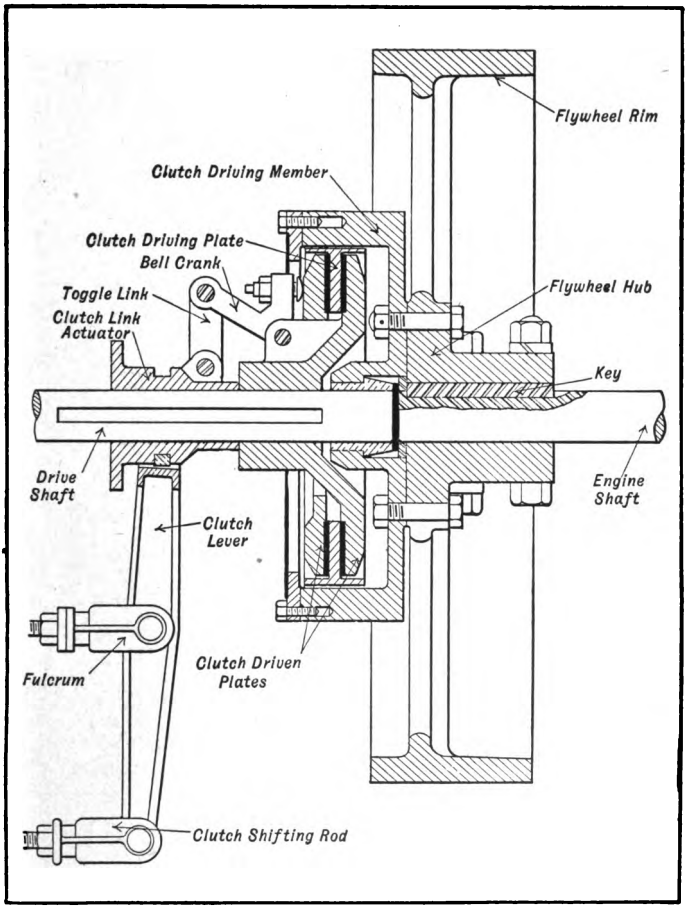

FIG. 96.—Sectional View of Master Clutch Used on Holt Tractors.

the clutch case. The engine shaft and drive shaft are independent when the clutch is disengaged. That is to say, the drive shaft may remain stationary while the

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fly-wheel revclves. Attached to the driving shaft is a flanged member which carries a number of bell cranks spaced equidistantly or 120 degrees apart. This driven member also carries a plate which is keyed to it and which must revolve with the driven shaft. This plate can move back and forth on its key so the two clutch-driven plates are in contact with the driving plate only when the clutch lever has moved the clutch-link actuator to the

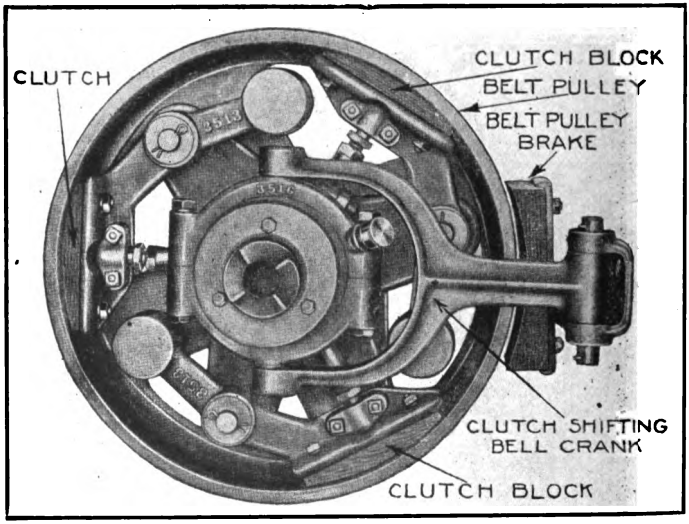

FIG. 97.—Clutch of Avery Tractor is Provided With Three Clutch Shoes.

position shown, where the toggle links are approximately vertical and the bell cranks are holding the driven and driving plates of the clutch into firm engagement.

When the clutch-link actuator is moved back the bell crank is pulled away from the outer clutch-driven plate, and as there is no pressure to maintain frictional contact

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between the driven and driving members, the fly-wheel of the motor may continue to revolve while the mechanism attached to the drive shaft becomes stationary. Wear between the clutch plates may be taken up by an adjustable contact member carried by the bell crank. A clutch of this type may be applied gradually and may

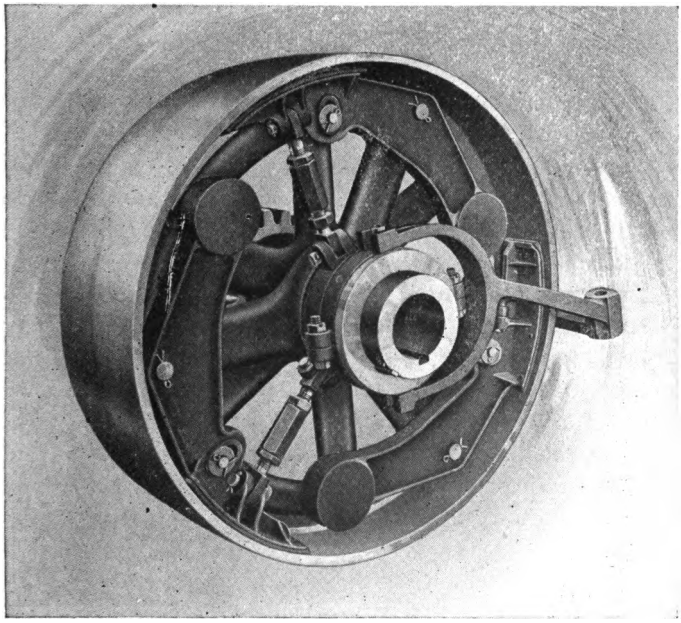

FIG. 98.—Clutch of Rumely Tractor Utilizes Three Friction Shoes Acting on Interior of Wheel Rim.

be allowed to slip to some extent while getting the tractor under way without doing any injury. When the clutch lever is operated to the limit of its movement in one direction the clutch is firmly engaged, while moving

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it to the other extreme position will insure complete disengagement.

Clutches shown at Figs. 97 and 98 are similar in construction. In these a series of contact blocks are carried at the end of counter-balanced, pivoted levers. The blocks are pushed out by means of a toggle linkage actuated by a clutch-shifting bell crank, in much the same manner as has been previously described. One member is attached to the crank shaft while the other rotates with the driving shaft. The clutch shown at Fig. 97 is used to bring a belt pulley into engagement with the engine shaft, though the principle may be reversed and the belt pulley represent a member attached to the engine fly-wheel while the spider which carries the clutch blocks and actuating mechanism would be attached to the independent transmission shaft.

Friction Disk and Roll Clutches.—Some tractor designers employ friction-wheel clutches instead of the types described. These operate on a different principle as the members are not locked together so that they revolve as a unit, but the driven member rotates the driving member which turns on a different plane. A double friction disk clutch such as used on the Heider is shown at Fig. 99, and its relation to the engine may be clearly ascertained. The fly-wheel has a fiber ring attached to it which serves as a driving member, while two disks are attached to the cross shaft which is placed at right angles to the crank shaft of the motor. These disks are adapted to be brought into contact with the fiber friction ring with a considerable degree of pressure.

The sketch at Fig. 100 shows the principle of operation. If the engine fly-wheel is turning in the direction indicated by the arrow and the friction disk A is brought in contact with it, the cross shaft to which the disk A is

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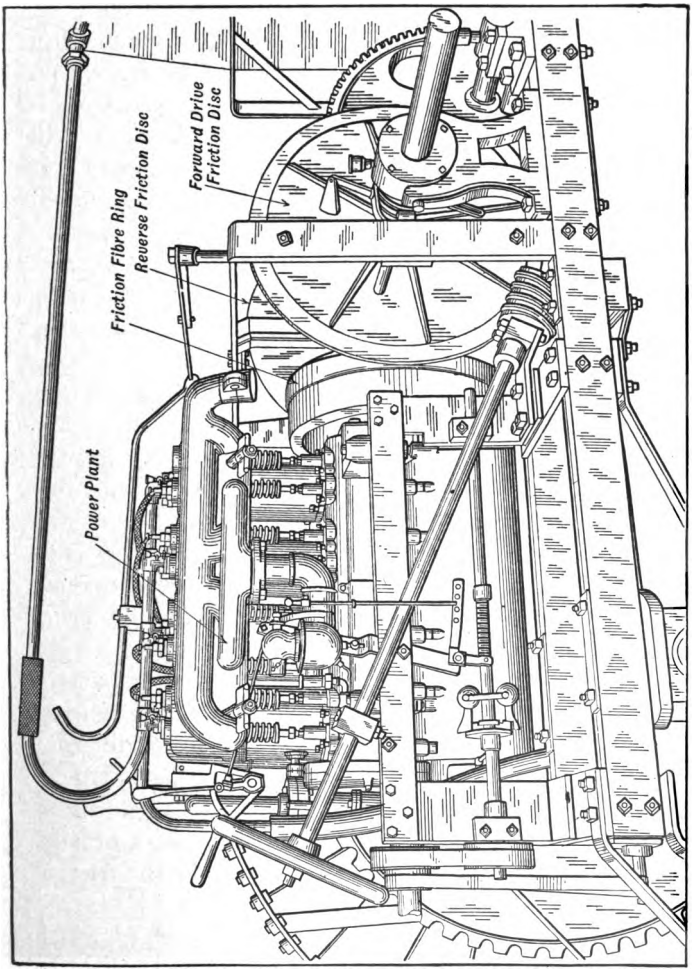

FIG. 99.—Side View of Power Plant and Friction Disc Clutch of Heider Tractor.

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attached will turn in the same direction, and as this carries a driving pinion which is in mesh with a driving gear on the differential casing of the counter shaft it will turn it in the opposite direction. As the connection from the counter shaft to the rear wheels is by chain and sprockets the rear wheels will turn in the same direction as the counter shaft does and the entire machine will move in the direction of the large arrow or forward. If conditions are reversed and the friction disk **A** is pulled out of engagement with the fly-wheel, while friction disk **B** is brought in contact with that member, the tractor will move backward because friction disk **B** will be revolved in a direction opposite to that friction member **A** turns in.

Another form of friction clutch in which a friction wheel is employed is shown at Figs. 101 and 102. The view of the mechanism at Fig. 101 shows clearly the mounting of the friction wheels for driving a movable cross shaft, which in this case is parallel with the engine crank shaft. This main driving shaft, which extends across the frame, is provided with a friction driving wheel at each end and carries a pair of sliding gears which may be engaged with either one or two gears on the transmission cross shaft placed immediately back of the main driving shaft that carries the friction wheels. The gears on the transmission cross shaft are of different diameters, one being smaller than the other, as is true of the sliding gears on the squared main shaft. Before discussing the method of obtaining speed changes or final drive it will be well to consider the action of the friction rollers.

The engine carries two large fly-wheel members, which are so arranged, one at each side of the frame, that the friction wheels employed for driving fit in an annular

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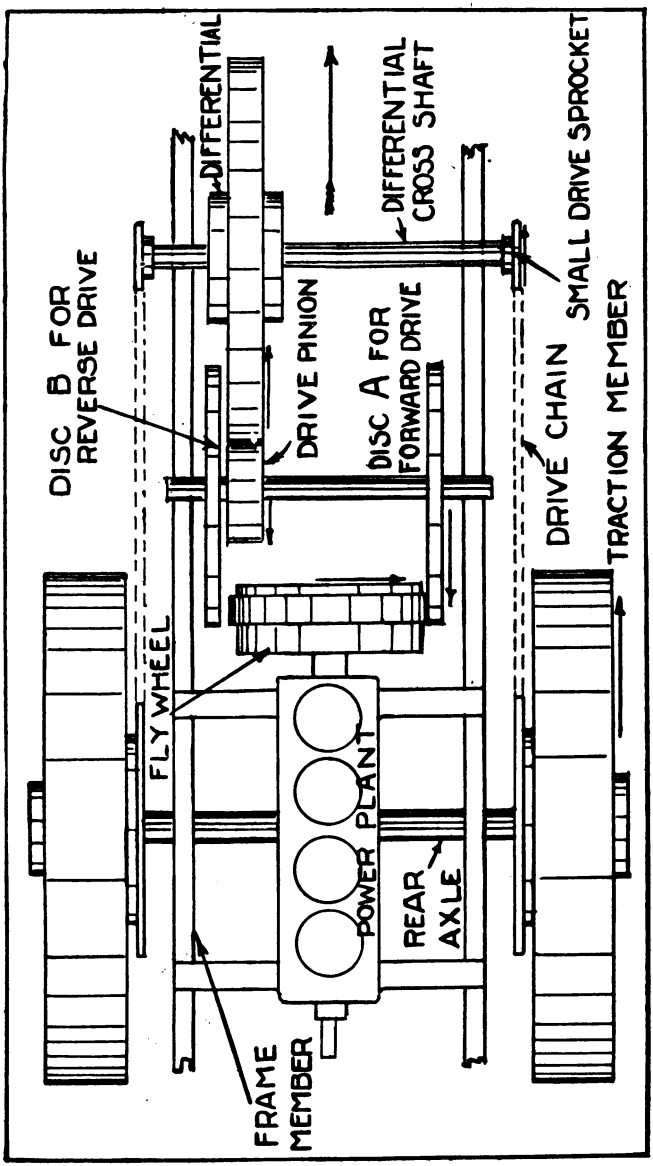

FIG. 100.—Explaining Action of Heider Double Disc Friction Clutch.

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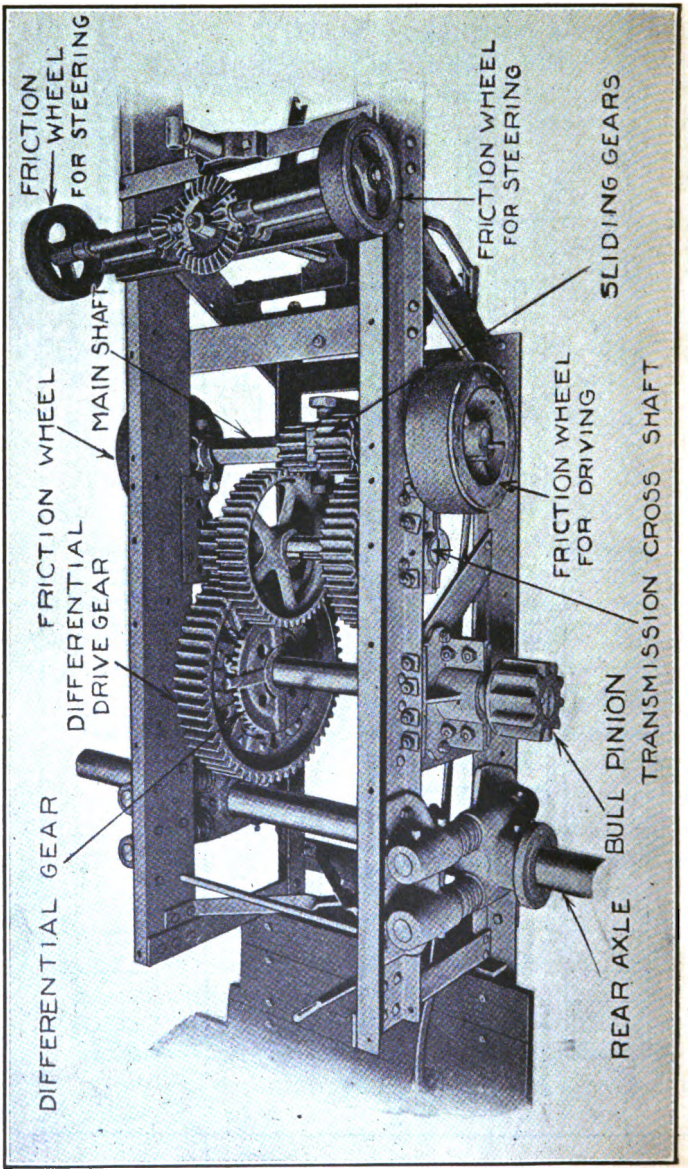

FIG. 101.—Clutch and Transmission Assembly of Ohio Tractor.

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channel machined between the inner and outer fly-wheel members. This is clearly shown at Fig. 102-A. The fly-wheel hub is enlarged and forms one driving member while the fly-wheel rim, which has a smooth and true inner periphery, forms the other driving member. When the friction driving wheels carried by the transmission main shaft are in the neutral position they are in the space between the inner and outer fly-wheel driving members, and as the friction roller is not in contact with either the hub or the rim of the fly-wheel, one member may revolve independently of the other.

To obtain the forward drive, the main shaft is rocked so the friction wheels are brought in contact with the inside of the fly-wheel rim. If this is turning in the direction indicated by the arrow, it will turn the friction roller in the same direction, and the main shaft is revolving in the same direction as the motor crank shaft. To obtain a reverse motion of the main shaft the friction rollers are disengaged from the interior of the fly-wheel rim and are pushed against the exterior of the fly-wheel hub, as indicated at C. This will produce a motion of the main shaft opposite in direction to that of the crank shaft. The leverage is proportioned so that very little pressure is necessary at the operating lever to insure positive drive. The shaft on which the friction pulleys are keyed is hung on pivoted or eccentric bearings, which are located in such a way that when the friction surfaces are brought in contact with each other they will automatically produce pressure enough to move the load, and as the resistance augments the driving pressure becomes stronger and the rolls can transmit the full amount of power generated by the engine. The friction wheels are made of paper or strawboard fiber and may be very easily replaced when worn.

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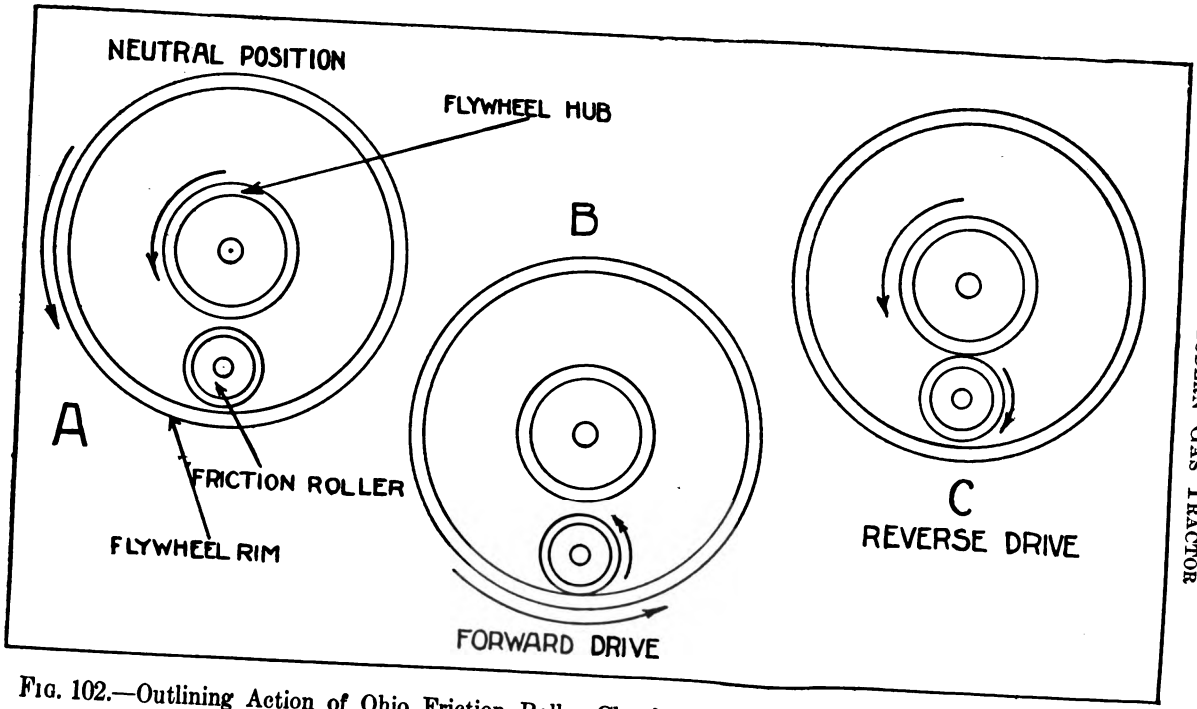

FIG. 102.—Outlining Action of Ohio Friction Roller Clutch. *A*—Friction Roller in Neutral Position. *B*—Roller in Forward Drive Position. *C*—Roller Placed to Obtain Reverse Motion.

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It is claimed that the friction drive methods cannot be compared to the friction clutch because it will give a much smoother and more flexible drive than is possible with any form of friction clutch. It is contended that the clutch is too positive a lock between the driving and driven parts, while the friction rollers are not so positive in their action. It is also advanced that in event of sudden shock the friction roller will slip to some extent, while with the friction clutch, which is positively locked, a sudden strain will result in breaking a gear or stressing of some of the transmission parts. With either of the friction drives described, a one-lever clutch control is obtained and one can start, stop, or reverse the tractor instantly by using but one control lever.

The methods of obtaining the changes of speed on the Ohio tractor may be easily understood by referring to illustration, Fig. 101. If the sliding gears are shifted along the main shaft, so that the smallest pinion on the main shaft is in mesh with the largest gear on the transmission cross shaft the slowest rear-wheel speed is obtained. If the largest pinion on the main shaft is slid into engagement with the smallest gear on the transmission cross shaft the highest rear-wheel speed will be obtained. If the sliding-gear member on the main shaft is placed at a neutral position so that it is not in mesh with either gear on the cross shaft, engaging the friction wheels and the fly-wheel will not produce motion of the tractor. The drive from the transmission cross shaft is by a pinion which engages a large gear attached to the differential spider. The differential gear is attached to a cross shaft to which the bull pinions, which drive the bull gears on the rear wheels, are attached. It will be apparent that with the friction roll clutch it will be possible to obtain the same number of speeds on the

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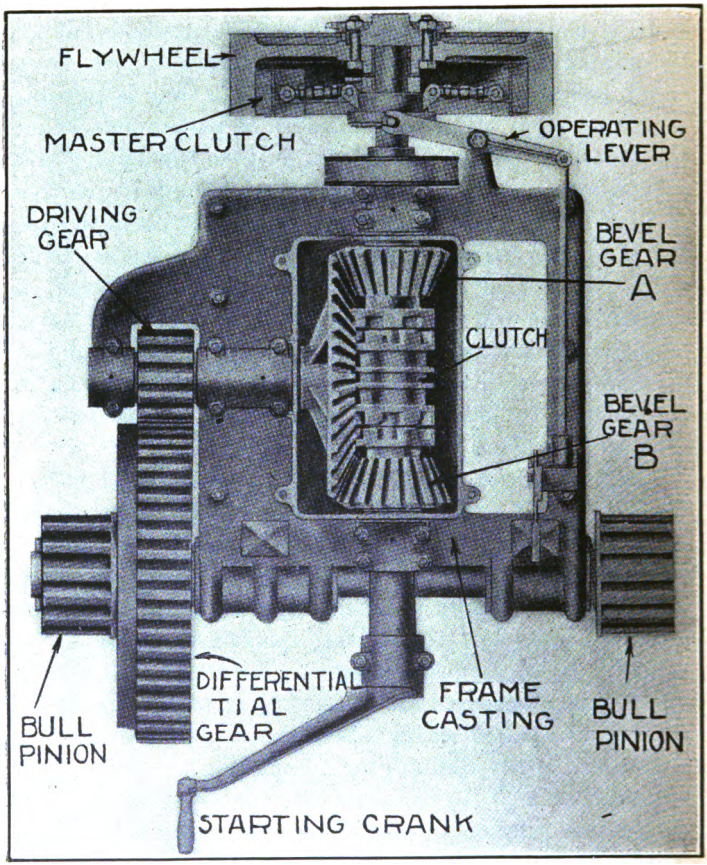

FIG. 103.—Master Clutch and Reversing Mechanism of Typical Tractor.

reverse drive as when the tractor is moving ahead.

Why Reversing Mechanism Is Needed.—Another difference between the steam and gas engines used for tractor propulsion is that the direction of crank-shaft rotation of the former may be easily reversed by a sim-

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ple mechanism which will reverse the flow of steam to the cylinders while the latter, as ordinarily made, can only run in one direction. When a steam engine is used for power no separate reversing mechanism is needed, but when the gas engine is utilized, owing to the fact that it runs only in one direction, it is necessary to provide some form of gearing that will permit the motion of the road wheels to be reversed even if the engine continues to revolve in the same direction as when the tractor is moving ahead.

Typical Reversing Mechanism.—A simple and efficient form of reversing mechanism is shown at Fig. 103. It consists of two bevel pinions placed on a continuation of the engine shaft and a bevel gear at right angles to them and in mesh with both of the pinions. The bevel-gear shaft carries a driving pinion of the spur type which meshes with the differential driving gear which in turn imparts motion to the bull pinions mounted on the counter shaft. The bevel pinions of the reversing gear normally revolve freely on the engine-shaft extension if the double-jaw clutch, which is keyed to the driving shaft, is in its neutral position. A master clutch is placed inside the engine fly-wheel so the driving shaft which carries the positive jaw clutch member may be placed out of engagement with the power plant when desired. The double positive clutch may be moved back and forth so that it can clutch either bevel gear **A** or bevel gear **B** to the driving shaft. When in the neutral position, if the master clutch is engaged, the tractor will not move because there is no driving connection between the bevel gearing and the driving shaft.

When the positive jaw clutch is moved on the shaft so it engages bevel gear **A** the drive is through **A** to the bevel gear on the short cross shaft and from thence to

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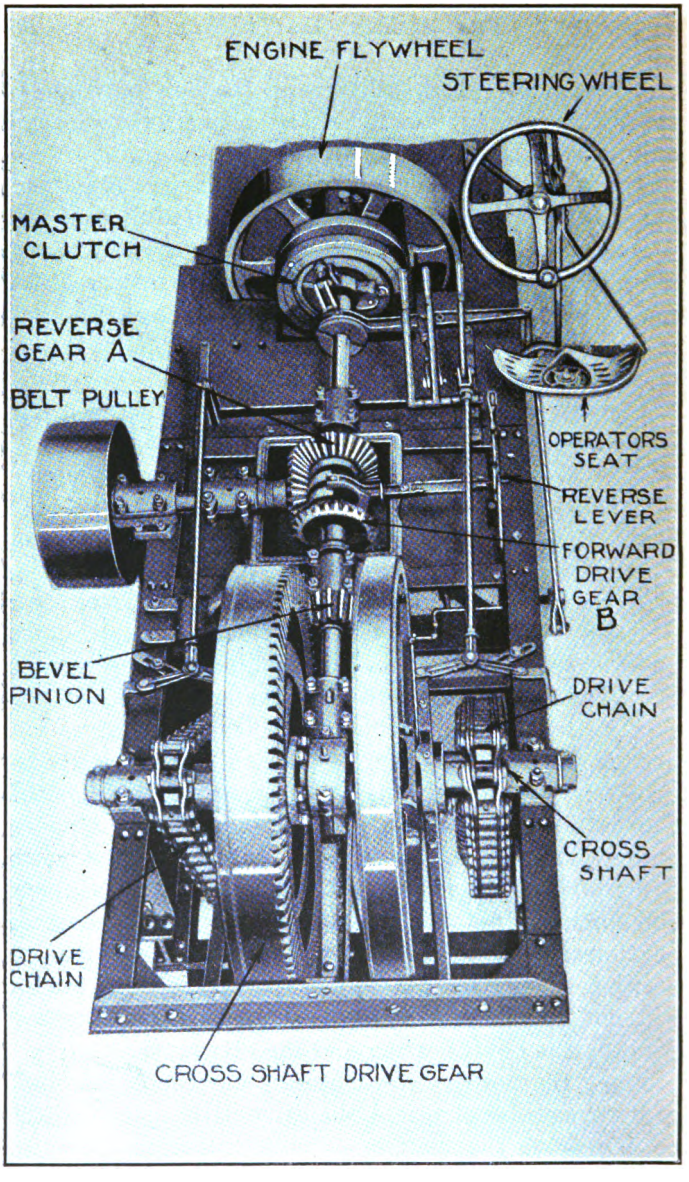

FIG. 104.—Showing Arrangement of Clutches and Drive Gears of Holt Caterpillar Tractor.

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the differential gear which turns the counter shaft on which the bull pinions are mounted, so the tractor is moving ahead. If the clutch is engaged with bevel gear **B**, the motion of the short cross shaft is reversed, and as the train of gearing runs in the opposite direction to that which obtains when bevel gear **A** is clutched, the tractor will move backward.

Another form of reversing gear, which operates on practically the same principle, is shown at Fig. 104. This is applied to the Holt Caterpillar Tread Tractor. In this mechanism, instead of the reduction between the driving shaft and the cross shaft being by means of spur pinion and gear, the drive is accomplished by a bevel pinion which drives the cross-shaft drive gear. The power is transmitted from the cross-shaft drive gear to the shaft on which small-diameter sprockets are mounted and from these driving chains are connected to the large driving sprockets which move the caterpillar tread traction member. The shaft from the master clutch is continued right through the reverse-gear box to a bearing placed between the cross-shaft drive gear and one of the traction member clutches. To obtain forward motion the clutch is moved so that it locks the bevel gear **B** which carries at the other end of the sleeve on which it is mounted the main bevel drive pinion, and this is turned in the same direction and at the same speed as the engine crank shaft when the master clutch in the engine fly-wheel is engaged. If the positive clutch is moved toward the front of the tractor so that it is clutched to the reverse gear **A** this member is locked to the drive shaft and the drive is then through the intermediate bevel pinion which causes the forward drive gear **B** to turn in a reverse direction and thus makes the tractor run backward. Sometimes the reverse gear is

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incorporated with the change speed gearing as in automobile practice, and on other forms of tractors it may be made a function of the friction disk or roll clutches as has been previously described.

Why Speed Changing Is Necessary.—Those who are familiar with the action of steam tractors may not recognize the necessity for change-speed gearing which is such an essential component of the gas-motor-propelled tractor. It has been demonstrated that the steam engine is more flexible than the gas engine and that the amount of power obtained can be varied by altering the amount of steam admitted to the cylinders. If the engine is running slowly and more power is needed the engine capacity may be increased materially without augmenting the speed of rotation and the power may be increased 50 or 100 per cent by using steam at higher pressure.

The internal combustion motor is flexible to a certain degree, provided that it is operating under conditions that are favorable to accelerating the motor speed by admitting gas to the cylinders. The power capacity or the mean effective pressure of the explosion in the gas-engine cylinder is limited arbitrarily, and after a certain point is reached it is not possible to increase the power output by supplying vapor at high pressure as is possible with a steam engine. It is customary in all tractors of the gasoline or kerosene burning type, where combustion takes place directly in the cylinders, to interpose change-speed gearing which will give two or more ratios of speed between the engine and the traction members.

There are occasions when a tractor is required to pull a heavy load slowly, as in plowing, where it is desirable not to exceed a speed of two miles an hour, whereas

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in other work, as in hauling on the road or moving from place to place without a load, considerable time would be lost if the tractor was operated on the low speed. Four or five miles an hour is a practical speed for hauling and usually some means is provided so the ratio of drive between the engine and the rear wheels may be increased. On some tractors three changes of speed are provided, in addition to a reverse motion, combined in the gear set. Most of the tractors in general use, however, have but two changes of speed, while many very practical machines have but one speed forward and reverse. Where the reverse gearing is incorporated in the change-speed gear set, but one ratio of drive is possible when the reverse gears are engaged, whereas when a separate reversing mechanism is utilized in connection with a change-speed gearing, as many speeds backward as there are forward may be obtained.

Action of Simple Change-speed Gears Outlined.—In order to explain the method of operation of a simple change-speed gear set, the essential e ements of a mechanism of this character are shown at Fig. 105. A gear attached to the engine crank shaft **A** drives the cross-shaft **B**. This carries a pair of sliding-gear members, which are keyed to it so that they must turn at the same speed, but which may be shifted so they will engage the gears on the cross shaft **C**, which in turn drives the rear wheels by means of pinions which mesh with the large gears attached to the traction members. One of the gears attached to the differential casing is 24 inches in diameter, the other gear is 27 inches. The small sliding pinion which is adapted to engage with a 24-inch gear is 8 inches in diameter, while that which will mesh with the larger or 27-inch gear is but 5 inches in diameter. Obviously, these dimensions are presented only to make

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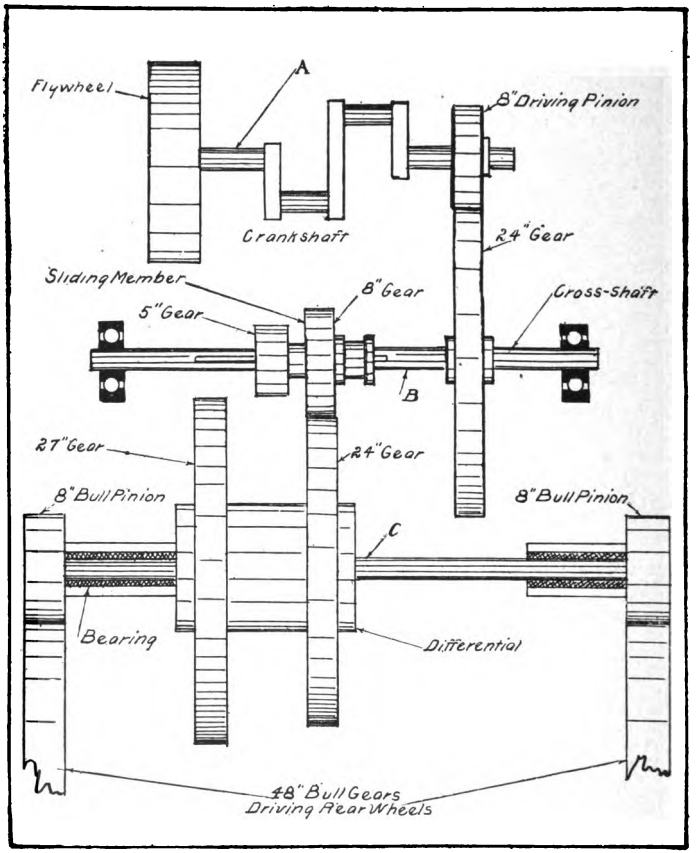

FIG. 105.—Diagram Showing Action of Speed Changing Gearing.

the explanation clear and are not necessarily dimensions that will be used in practical service.

We will assume that the driving gear on the engine crank shaft is 8 inches in diameter and meshes with a large driving gear on the cross shaft **B** which is 24 inches in diameter. This means that cross shaft **B** will turn at

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one-third the speed of crank shaft **A**. If the 8-inch gear on the cross shaft **B** is meshed with the 24-inch gear on the differential cross shaft **C** the shaft **C** will revolve at one-third the speed of shaft **B**. If the shaft **C** carries a pinion 8 inches in diameter, which meshes with a bull gear 48 inches in diameter, the rear wheel will turn at one-sixth the speed of the differential cross shaft. Assume that the crank shaft **A** of the engine is making 600 revolutions per minute, then cross shaft **B** will revolve at one-third its speed or two hundred revolutions per minute. On account of the reduction between the cross shaft **B** and the differential shaft **C** the speed of the latter will be reduced to one-third of that of the former or 66.66 revolutions per minute. There is a reduction of six to one between the large bull gear on the wheel and the bull pinion on the differential shaft, so the rear wheels will turn but 10.11 revolutions per minute. Assuming that the driving wheels of the tractors are 72 inches in diameter, which gives a circumference of 18.85 feet, it will be evident that it will take 280 revolutions of the wheel to cover one mile. As the rear wheel makes approximately ten revolutions, this will be equivalent to a speed about one mile in twenty-eight minutes or a little faster than two miles an hour.

Suppose that a still slower speed than two miles an hour is desired, then the 5-inch pinion on the cross shaft **B** will be engaged with the 27-inch gear on the differential cross shaft. The ratio of drive between **B** and **C** will then be lower. If cross shaft **B** turns at 200 revolutions per minute and the ratio of drive is as five to twenty-seven, which is equal to a ratio of 5.40 to 1, this means that the cross shaft **C** will revolve at about 37 revolutions per minute instead of 66, and the speed will be reduced to less than one mile an hour. If it is desired

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to increase the speed of the tractor to 4 miles an hour on the high speed and 2 miles an hour on the slow speed, it is only necessary to change the ratio of drive between the engine crank shaft A and the cross shaft of the transmission B. The speed may be also augmented by using a 16-inch bull pinion instead of the 8-inch diameter member.

A typical plan view which outlines the relation of the various parts of the driving and change-speed mechanism of the Morris Tractor is shown at Fig. 106. In this the engine crank shaft is mounted across the frame and parallel with the transmission and differential cross shaft and the rear axle. The change-speed gearing is mounted on the transmission cross shaft, and consists of two gears which are in mesh with two driving members carried by the clutch sleeve mounted on the crank-shaft extension. These gears are brought in engagement with the transmission cross shaft on which they normally revolve free by a sliding internal clutch which drives the transmission cross shaft, by a squared end. If this jaw clutch is moved out to the limit of its travel the larger speed-reduction gears are engaged, whereas if the internal clutch is moved to the limit of its travel toward the frame member, the larger of the two gears on the cross shaft is engaged with the smallest driving gear on the crank shaft. When in the position shown in drawing the cross shaft gear-driving clutch is in a neutral position and the motor may turn without producing any movement of the cross shaft. The gear which acts as a driving member to turn the large gear attached to the differential casing is normally free to revolve on the transmission cross shaft and is in mesh with a gear carried on a small shaft below it at all times as well as with the differential drive gear. The reverse cross shaft

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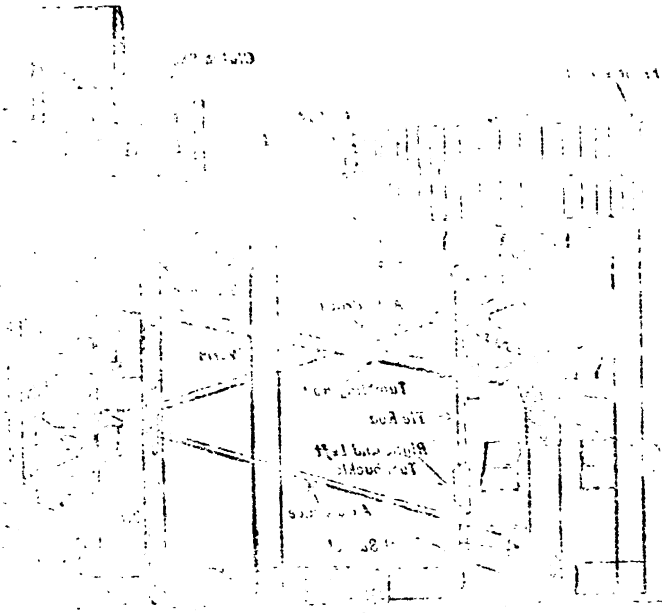

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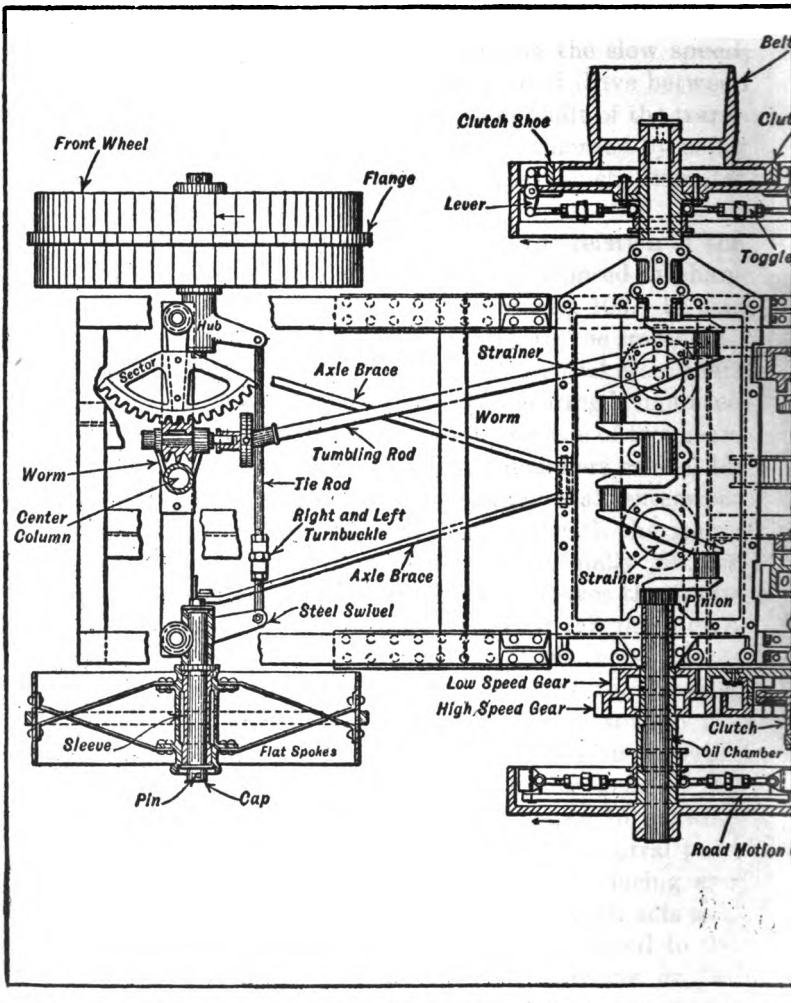

Fig. 106—Plan View of Morris Tractor Mechanism, Outlining Arrange

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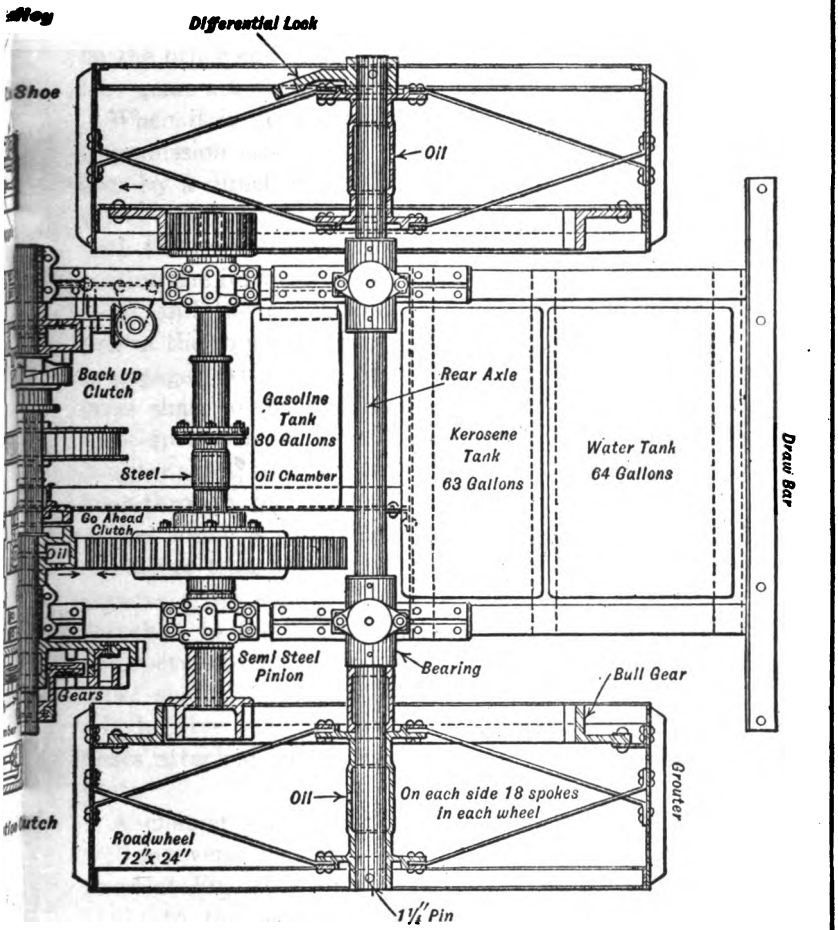

ment of Engine Crankshaft, Speed Changing Mechanism and Rear Axle.

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carries another gear which engages with a normally freely-revolving member placed near the frame member on the other end of the transmission cross shaft. These four gears are always in mesh.

When it is desired to drive the tractor forward, the transmission cross shaft is made to drive the go-ahead gear by a direct connection produced by a positive jaw clutch which clutches the loose gear so that it must turn with the transmission cross shaft. To obtain a reverse motion the forward drive clutch is pulled out of engagement and the reverse or back-up clutch at the other side of the square portion of the transmission cross shaft is engaged with its gear. The drive is then from the cross shaft to the gear which has been clutched by the back-up clutch member and from thence to the reverse counter shaft, back from this to the differential driving gear through the medium of the differential gear drive pinion which is revolving idly on the shaft and serving merely to transmit the reverse motion produced by the reverse cross shaft, thence to the large driving gear attached to the differential casing. The speed reduction between the traction members and the differential cross shaft is accomplished by means of bull pinions which drive the traction member by internal spur bull gears attached to the wheel rim by means of an angle plate.

A change speed gearing in which speed changes as well as reverse gearing are incorporated in one unit is outlined at Fig. 107. The drive from the engine is by a chain to the large driving sprocket which drives the gear A on the main shaft by means of a sleeve to which both sprockets and gear are connected. The gear A is always in engagement with the gear B which drives the counter shaft. The splined driving sleeve C is attached

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to the differential gear casing and is hollow so that the shaft driving the bull pinions can pass through it. With the sliding clutch **D** in the position indicated the splined differential drive shaft **C** is locked firmly to the driving gear **A**, and the drive is direct from the engine to the differential casing. The only reduction of speed obtained is because of the varying diameter of the drive sprocket on the transmission and that on the engine crank shaft.

If the sliding clutch **D** is moved over until the sprocket

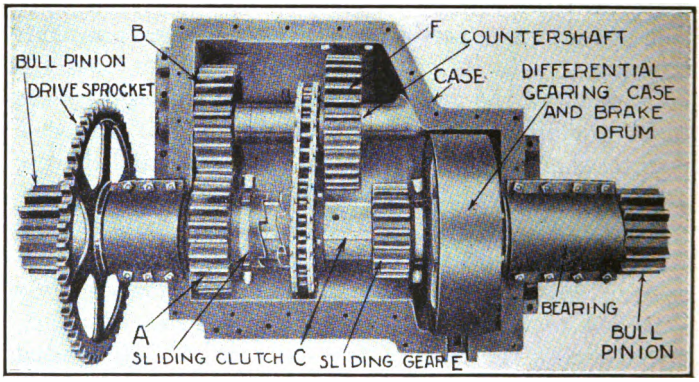

FIG. 107.—View of Transmission and Differential Unit With Cover Removed.

on the differential case drive shaft, which normally revolves free upon it, is clutched to that member then a reverse motion will be obtained. The drive from the engine is to the drive sprocket of the transmission gearing, which turns in the same direction as the engine crank shaft and, of course, carries the gear **A** with it. The gear **B** turns in a reverse direction and the counter shaft is revolved in a reverse direction to that of the engine crank shaft. The splined differential drive shaft

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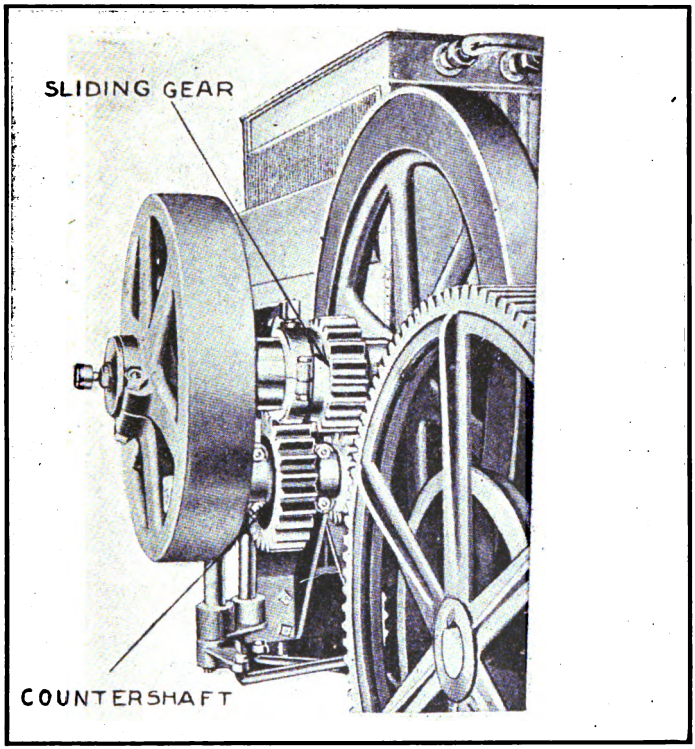

FIG. 108.—View of Change Speed Gearing of I. H. C. Two Speed Tractor With Sliding Gear in Neutral Position.

C is now free to turn inside of gear **A** and is driven in the same direction as the counter shaft by means of the driving chain, which now imparts motion from the counter shaft to the splined differential case drive sleeve **C**. The bull pinions which are driven from the differential gear are now turning in a direction opposite to that of the engine crank shaft.

In order to obtain the high speed the sliding clutch **D**

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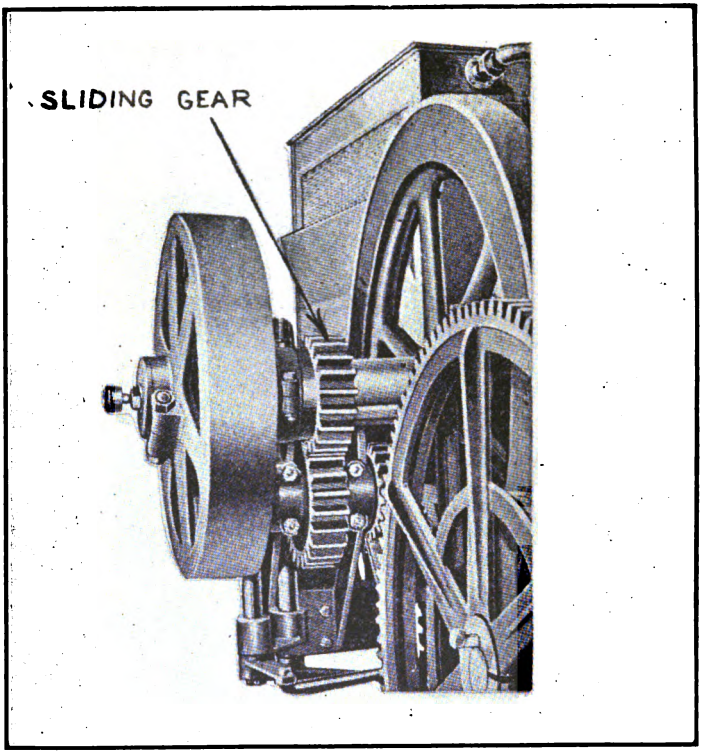

FIG. 109.—Sliding Gear of I. H. C. Two Speed Transmission in Low Speed Position.

is placed in a neutral position so that it is out of mesh with either gear **A** or the reverse sprocket. The sliding gear **E** which is keyed to the differential drive sleeve **C** is then slid into mesh with the gear **F** on the counter shaft. The drive from the engine to the drive sprocket turns the gear **A** in the same direction as the engine revolves. The counter shaft is turned in a reverse direction by the constant mesh gear **B** which turns **E** in the

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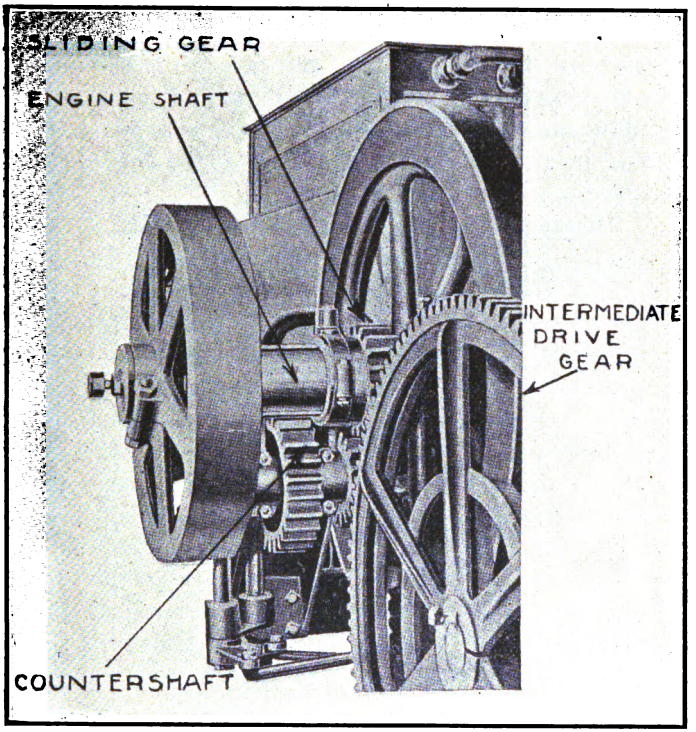

FIG. 110.—Sliding Gear of I. H. C. Two Speed Transmission in Direct Drive Position.

same direction and at the same speed as gear **B**. The direction is reversed by the sliding gear **E** and the differential is driven in the same direction as the transmission drive sprocket but at a higher rate of speed on account of the difference in size between gear **F** and sliding gear **E**. The reason that the highest speed is obtained through gearing instead of on the direct drive is because it is desirable to do the heavy work through as few gears as possible because each set of gears in mesh increases the

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friction and decreases the efficiency of the drive. The lowest speed forward in this transmission is the one on which heavy work such as ploughing and breaking will be done, and more of the engine power is available than would be the case if there was an added loss through another pair of gears.

A simple sliding gear utilized on the I. H. C. two-speed tractors is shown at Figs. 108 to 110 inclusive. In this, the sliding gear member is carried on the engine shaft in such a way that it may be engaged with the intermediate drive gear either through the counter shaft carried below it or by direct connection with the intermediate gear. At Fig. 108 the sliding gear is shown in a neutral position. The gearing on the cross shaft cannot turn because the sliding gear is not in mesh with the large gear on the counter shaft. When the sliding gear is moved to the position shown at Fig. 109, the gearing is in low speed. The gear carried on the engine shaft is driving a larger gear on the counter shaft which in turn is driving the intermediate gear through a small spur pinion. When the sliding gear is moved over so that it is out of mesh with the large gear on the counter shaft and engaged directly with the intermediate drive gear, the highest speed ratio is obtained.

The Differential Gear and Its Use.—The differential gearing is one of the most important parts of the gas tractor as well as the automobile. This arrangement of gearing permits the rear wheels to revolve at different speeds and at the same time act to drive the tractor. When a tractor turns a corner the inner wheel must revolve slower than the outer one because it is not covering as much ground. The differential gear makes this possible in a very simple manner. The construction of a typical differential gear is shown in outline at Fig.

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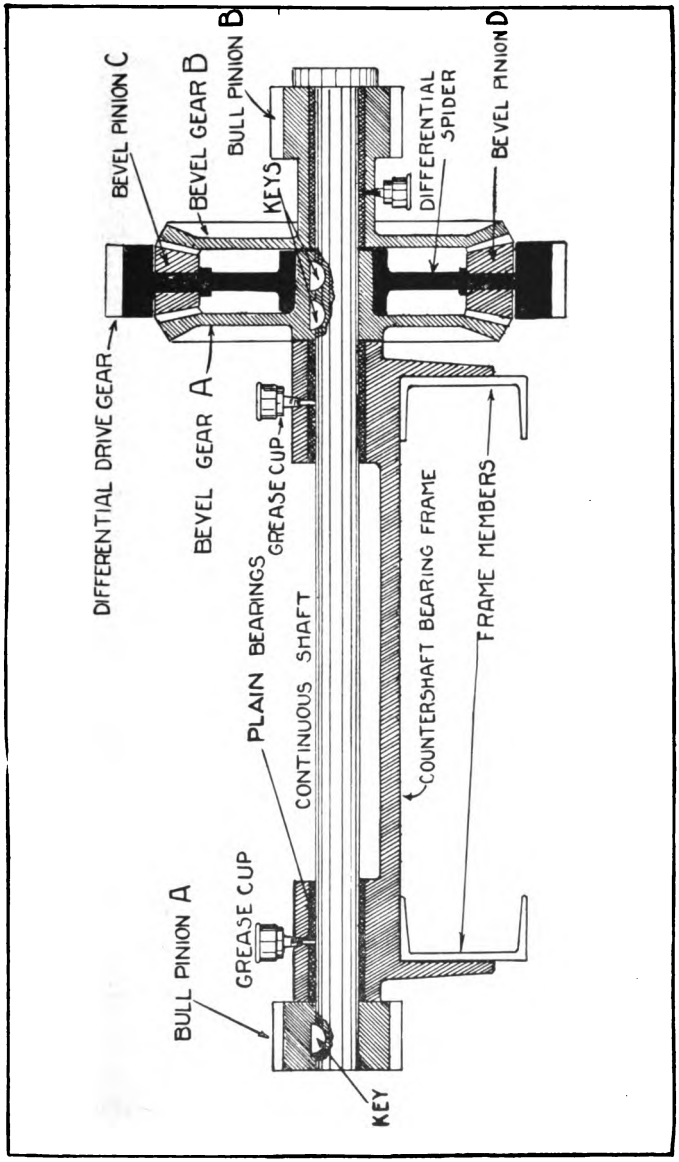

FIG. 111.—Sectional View of Typical Countershaft With Differential Gear in Place.

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111 in the form that it is usually employed on gas tractors.

In this application the differential gear is mounted on a cross shaft, which is the usual method of installing it on both gas and steam-propelled traction engines. The bull pinion **A** is attached to a continuous shaft which passes through the center of the differential gearing and which is driven by the bevel gear **A**. The bull pinion **B** is attached to a sleeve forming part of bevel gear **B** and can revolve independently of the continuous through shaft when desired. The differential driving gear, which is turned by the source of power, is mounted independent of the continuous shaft and is coupled to bevel gears **A** and **B** only through the medium of bevel pinions **C** and **D**, which are attached to and revolve upon studs carried by the differential spider.

Assuming that all the gears are in mesh, as outlined, if the resistance to traction is the same at both rear wheels the power applied at the differential drive gear will be directed to both bull pinions **A** and **B**, and the entire assembly, which is comprised of the differential spider and pinions attached to it and the bevel gears **A** and **B** which drive the bull pinions, will revolve as a unit.

Should the traction resistance against the driving wheels vary, as is the case when the tractor turns a corner, or deviates otherwise from a straight course, so that one wheel tends to revolve faster than the other, the small bevel pinions **C** and **D** will not only turn around on the studs on which they are mounted but at the same time will run around the gears **A** and **B** because the differential spider is being rotated by the engine. When turning a corner the other wheel must revolve so much faster than the inner member that it is just as

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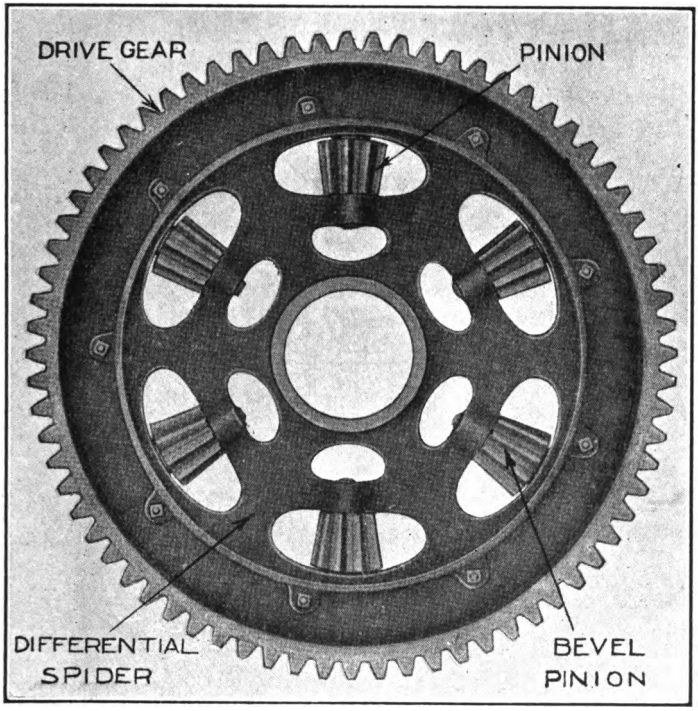

FIG. 112.—The Differential Spider With Bevel Pinions and Spur Drive Gear Attached.

though one of the wheels was held almost stationary and the other turned.

The action of the differential pinions may be clearly understood by giving due consideration to the following principles: The same resistance at the point of contact between the driving wheels and the ground prevents the pinions from revolving on their own studs, and in this case they act simply as keying members between bevel gears **A** and **B** and are carried around by the differential spider. If the resistance upon bull pinion **A** is

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greater than that on bull pinion B the differential spider will rotate forward with the wheel offering the least resistance and the differential pinions will turn on their studs and run over the surface of the gear which tends to remain stationary, this obviously being the one against which there is the greatest resistance. The differential pinions can thus turn independently of one bevel gear wheel and run over its surface without turning it and at the same time act as clutching members of sufficient capacity to carry the other bevel gear and the bull pinion

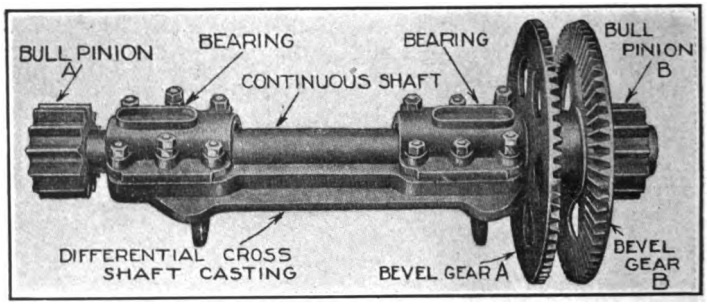

FIG. 113.—Countershaft With Differential Spider Outlined at Fig. 112 Removed.

attached to it in the same direction as the differential spider and at a ratio of speed which will depend upon the difference in resistance between the friction members and the ground.

While the differential described is of the bevel-pinion type, and is the form generally used on gas tractors, the differential effect can be obtained by a combination of spur pinions and spur gears just as well. The appearance of the differential spider and the manner in which the bevel pinions are carried around with it is clearly outlined at Fig. 112. This also shows the method of

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bolting the drive gear to the differential spider. At Fig. 113 the other parts comprising the differential gear assembly, when the differential spider shown at Fig. 112 is removed, are clearly shown.

It is sometimes desirable to lock the differential gear so that it will be temporarily out of commission. This condition would be desirable if one of the wheels was in a mud hole where the resistance to its turning was slight, while the other was on hard ground which offered considerable resistance to its moving. When the power was applied the wheel that was in the mud hole would revolve without driving the tractor, as the difference in traction resistance between the ground and the two wheels would be too great. If the two bevel-gear members A and B and the differential spider were locked together by a bolt passing through the three of them, or its mechanical equivalent, then the power would be applied to both wheels and the tractor would pull itself out onto the firm road surface again. Obviously, before attempting to turn any corners or deviate from a straight path it would be necessary to remove the locking bolt so that the differential could function properly again.

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CHAPTER VIII.

THE TRACTOR FRAME, WHEELS AND AXLES.

Construction of Tractor Frames—Typical Frames Described—Why Three Point Support is Needed—Facts Concerning Tractor Wheels—Methods of Construction—Action and Advantages of the Caterpillar Tread—Tractor Front Axles—How Tractors are Steered—Automatic Steering Arrangements—Methods of Final Drive—The Conventional Method—Use of Chains and Sprockets—Live Axle Forms.

Construction of Tractor Frames.—One of the important components of the modern gas tractor and that which determines whether the machine will be enduring and efficient, is the frame. This serves to tie and support all other parts of the machinery and is depended on to maintain proper alignment between the various components of the power generating and transmission groups. If the design of this foundation is neglected or slighted the efficiency of the tractor will be materially reduced. A light, poorly braced frame will permit the various parts to get out of line if the tractor is operated over irregular or rough surfaces, such as obtain in most fields.

The frame must be heavy enough to furnish a substantial foundation for the power plant as a frame that was inadequate in strength would produce rapid deterioration of the mechanism because it would subject it to strains that it was not designed to withstand. When bearings cramp out of line much more power is con-

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sumed in bearing friction and this in turn means greater wear of the components. It is imperative that the frame be of sufficient size and have strength enough to furnish a practically vibrationless bed for the engine and have room to support the engine, radiator, transmission mechanism, fuel tanks, and operators' platform. In order to obtain the strength that is desirable in frame construction the usual material employed is the merchant structural shapes in steel, such as I beams, angles or channels.

These members usually extend from front to rear and join the axles and are commonly held together crosswise by other cross pieces which are well braced by liberal gussets or fish plates. The frame is one member that will rarely need replacing, therefore it is usually a built-up structure composed of members permanently fastened together by riveting. The frame should support the bearings to which the important members of the transmission and rear axle are fastened, and it is good practice to attach a sub-frame or inner frame of steel to the main frame for supporting the engine and related parts. Some manufacturers build up the frame of steel plates firmly riveted together and following bridge construction in that the area of the section is greatest at the point farthest away from the supports. Tractor frames are sometimes built up of two main castings, one at the front, the other at the rear, joined by channels or steel angles. The front casting serves as a point of attachment for the front axle, while the rear member is often employed to support the important shafts and bearings.

Typical Frames Described.—A typical tractor frame from which the power plant and related parts has been removed is shown at Fig. 114. It will be seen that

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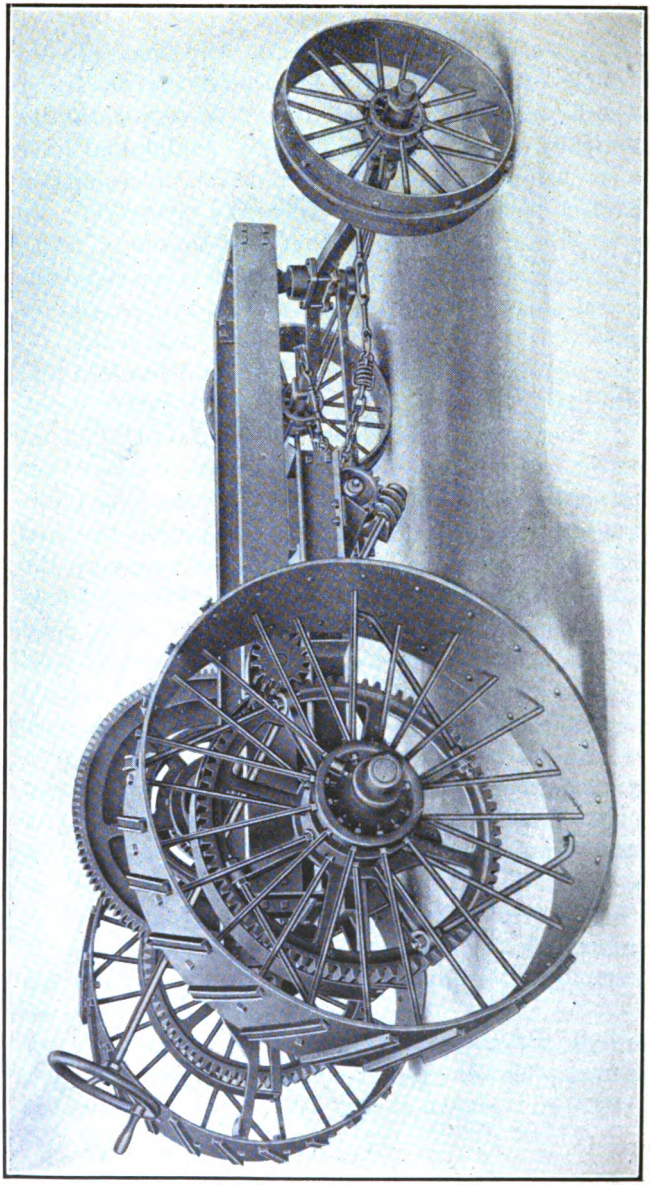

FIG. 114.—Frame and Running Gear Assembly of I. H. C. "Mogul" Tractor.

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the frame proper is composed of steel channels, which are firmly attached together by bolts. A sub-frame is carried beneath the main frame and forms a support for the power plant. The important parts of the transmission mechanism are clearly shown as is the general construction of the front and rear wheels and steering mechanism. The frame shown at Fig. 115 is one from which the wheels have been removed and shows clearly the method of construction ordinarily followed on tractors of conventional design. The frame consists of two side members cambered in at the front at a point just forward of the steering gear, which are joined together by means of cross braces of steel channels, angles, and plain bar stock. The engine is located just forward of the intermediate drive gear and is arranged in such a way that this member meshes with a gear on the engine crank shaft. The change speed and reverse gearing are thoroughly encased and form a unit with the differential cross shaft, which carries the bull pinions which drive the rear wheels through the medium of the bull gears. The operator's platform and the drawbar to which the ploughs or other machinery are attached are also clearly shown at the rear end of the machine.

The method of using a casting for the rear end of the tractor frame and the advantages of this construction are clearly illustrated at Fig. 116. It will be observed that the counter shaft and rear axle are carried in substantial cast frame members which are attached to the side channels very securely. As the boxes which serve as bearings for the counter shaft and rear axle form part of the same casting member it will be apparent that a very stiff construction that will prevent frame distortion is utilized to secure the advantages accruing from absolute alinement of driving and driven members.

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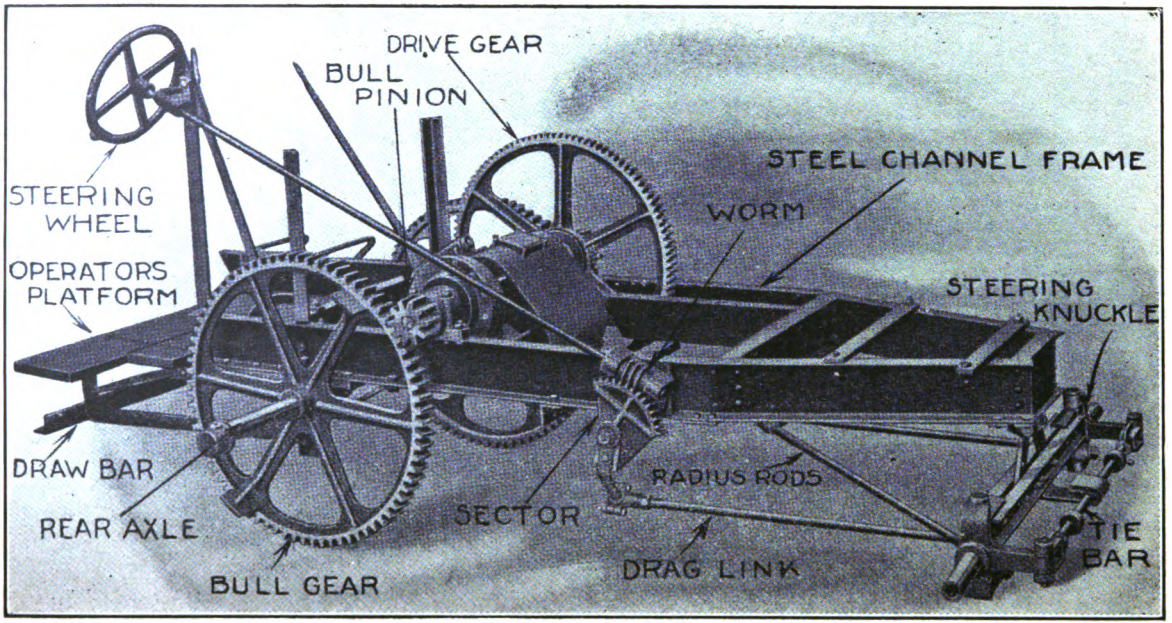

FIG. 115.—Frame Assembly of Typical Gas Tractor, Showing Driving and Steering Gearing.

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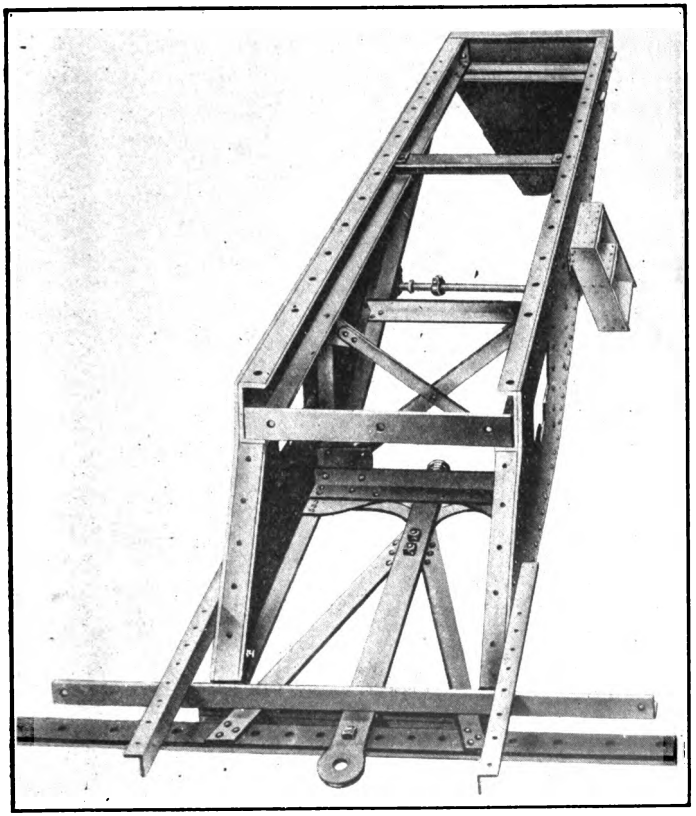

FIG. 115A.—Frame of the "Twin City 40" Gas Tractor Built of Standard Structural Shapes, Such as Angles and Channels Joined Together by Flat Bars and Braced by Plates. An Exceptionally Substantial Design Representative of Best Construction.

Why Three-point Support Is Needed.—The average traction engine is designed for rough service and is often operated under conditions where a more finely

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constructed piece of machinery would soon be ruined. The fields in which tractors are operated are full of hollows and hummocks and in order to be practical the tractor frame should be mounted in such a way that it will be able to tilt when one of the wheels is lower or higher than its mate, without stressing the frame side members and imposing strains on the mechanism. The three-point method of support is the simplest way of accom-

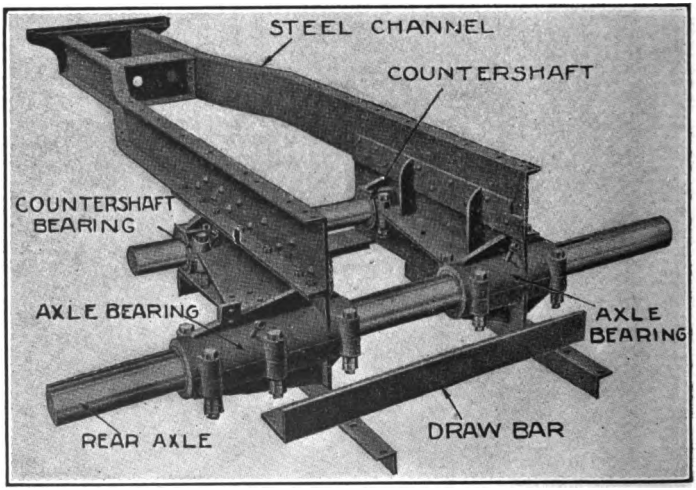

FIG. 116.—Rear End of I. H. C. Tractor Frame, Showing Substantial Cast Members Serving to Support Countershaft and Rear Axle Bearings.

plishing this end. With a three-wheel tractor a three-point support is obtained by the arrangement of the supporting members, but when four wheels are utilized it is necessary to design the tractor so that it can tilt without throwing the machinery out of line. This means that the entire frame must move as a rigid unit without appreciable distortion.

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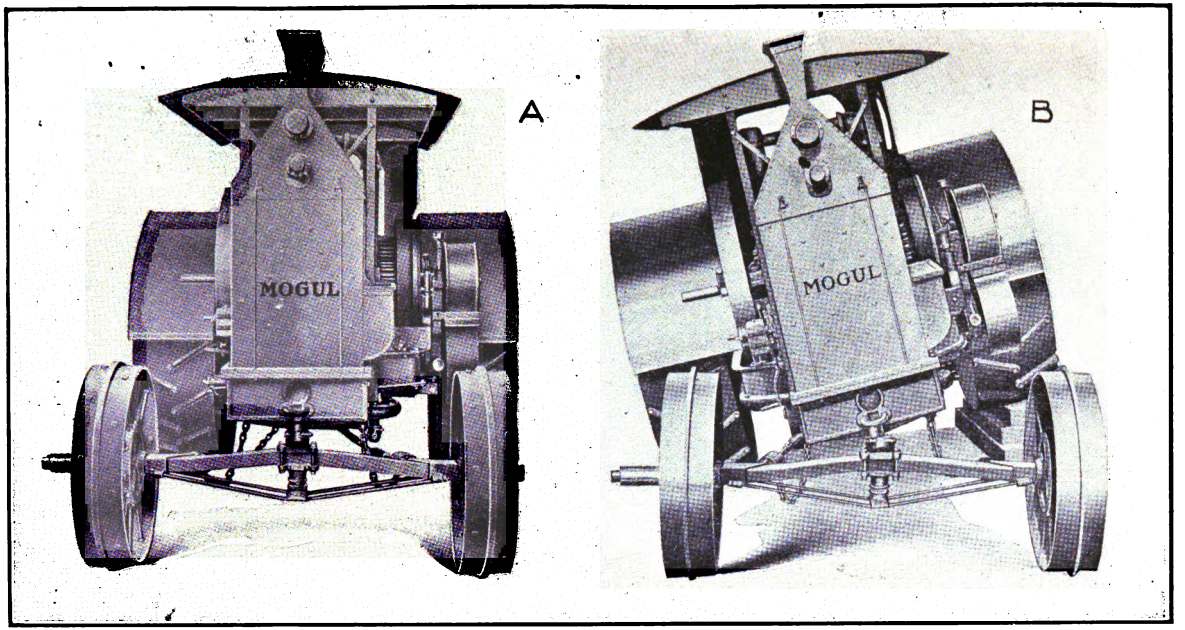

FIG. 117.—How Pivoted Solid Front Axle Permits Frame Movement Without Distortion by Giving Three Point Support. *A*—On Level Ground. *B*—Rear Wheel Surmounting an Obstacle.

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Owing to the method of drive employed on most tractors of the conventional pattern it is not possible to have the rear axle movable relative to the frame structure. It is therefore the rule to arrange the front axle so that it will be supported or pivoted at one point at its center to permit the frame to tilt as conditions dictate. The two views at Fig. 117 outline the method of attaching the swinging front axle to the frame so that it may move with minimum friction when operated to steer the tractor and at the same time permit the frame to tilt. The view at A shows the front end of the tractor with the frame level, which condition obtains when the tractor is operated on a comparatively smooth surface. At B one of the rear wheels of the tractor has been blocked up in such a way that it is a foot or more higher than the one on the opposite side. It will be evident that the entire frame and mechanism has tilted over to one side on the single point of support over the front axle, while that member remains level. Obviously, the conditions may be reversed, the rear wheels being on an even plane and the frame level, but the front axle tilted at an angle as will be the case if one of the front wheels was passing over an obstacle.

Three-point support is not difficult to obtain when the one-piece swinging front axle is utilized because a pivoted point is necessary to secure easy steering. When the Ackerman type axle is used, however, this being the form in which the wheels are carried by steering knuckles, it would not be necessary to supply the single pivotal point of support if it were not imperative to have the three-point method of suspension. Fig. 118 outlines the construction of a skeleton type movable spindle axle which is hinged at a central point to permit the front wheels to tilt as indicated in the illustration.

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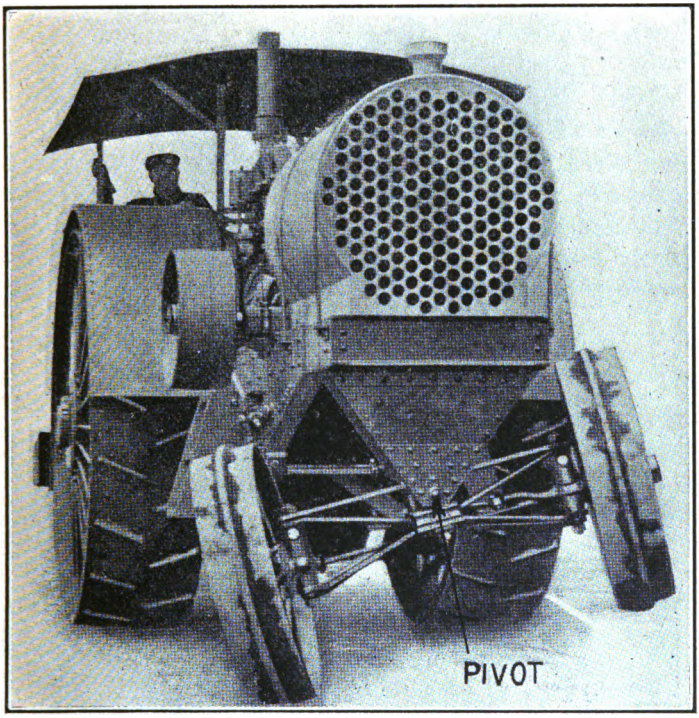

FIG. 118.—Showing Arrangement of Ackerman Front Axle to Obtain Three Point Support of Tractor Frame.

Gas tractors, as a rule, are not mounted on springs because their speed of travel is slow and the large wheels employed reduce the need for springs which are so necessary with automobiles or horse-drawn vehicles. The front view of a Phoenix tractor outlined at Fig. 119 shows the method of utilizing a spring mounting for the front axle and at the same time obtaining the desired degree of flexibility essential to a practical three-point support running gear. Two springs are used, one at each side of

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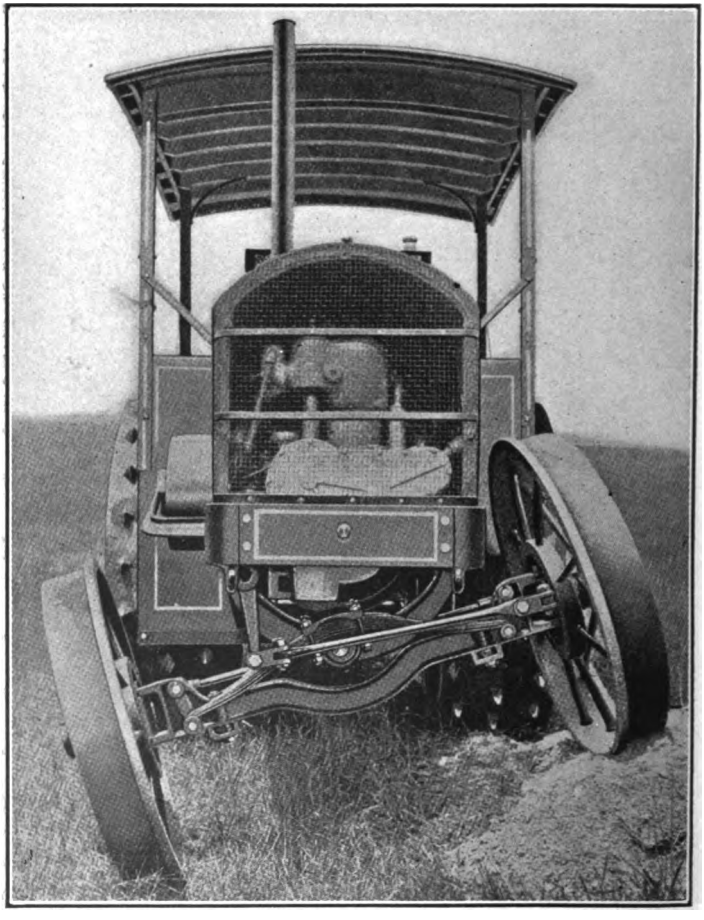

FIG. 119.—Method of Mounting Front End of Phoenix Tractor Frame on Springs Designed to Permit Three Point Suspension Principle.

the axle, and these carry a bearing at their center which rocks on a stud attached to the bottom of the curved

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front frame member. The construction is so clearly shown in illustration that further description is unnecessary.

Facts Concerning Tractor Wheels.—Gas tractor frames may be mounted on either three or four wheels. When a three-wheel construction is employed it is sometimes the two front wheels that are used for steering with a single large driving member and in some cases the two front wheels serve as driving members while a single

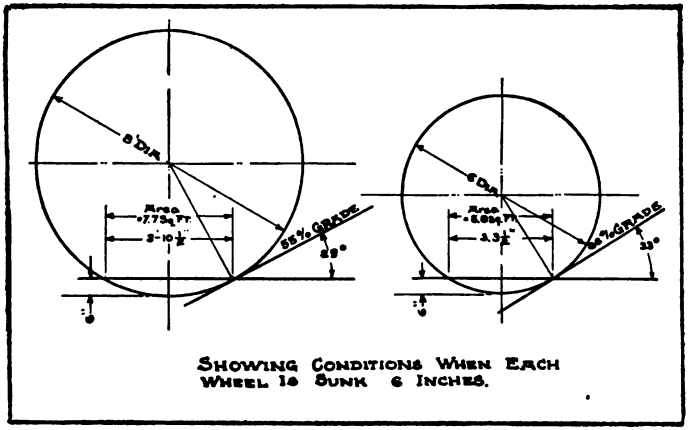

FIG. 120.—Showing Advantages of Large Wheels for Tractor Driving Members.

rear wheel serves to steer the vehicle. The four-wheel construction is the most conventional, however, and the two front wheels are smaller in diameter and much lighter than the rear wheels and are used practically only for steering purposes as most of the tractor weight, in some cases 80 or 90 per cent, is carried over the rear or traction members. When a single rear driving wheel is employed no differential gear is needed, though most engineers prefer to use two traction members and obtain

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a more effective contact area between driving members and the ground. The front wheels are generally of the same type and are a built-up structure composed of a hub from which circular section spokes of steel rod radiate to the steel rim. Generally a raised collar or flange is shrunk onto the smooth tire to prevent side slip. In some cases the wheels are made in one piece and have the rim, spokes and hub cast integral.

The traction wheels vary from twenty to thirty-two inches wide and from six to eight feet in diameter. Most engineers favor a large wheel because this will bridge over irregularities of the field surface easier than the wheels of lesser diameter, have more area of contact with the ground and are much more efficient as driving members. The advantages when a large wheel is used compared to one of smaller diameter under similar conditions are clearly outlined at Fig. 120. In this case it is assumed that each wheel has sunk six inches into the ground. It will be noted that the area of contact of the 6-foot diameter wheel is but 5.8 square feet while that of the 8-foot diameter member is 7.75 square feet. In order to pull the tractor out of the rut the engine must exert as much power with a 6-foot wheel as would be necessary to pull it up a 66 per cent grade. With the 8-foot wheel the amount o angularity is reduced and the grade corresponds to but 55 per cent. It will be evident by study of diagram why the large wheel is superior to the member of less diameter.

Methods of Construction.—The best driving wheel construction is known as the built-up type of wheel which is lighter than the cast wheel and which has ample strength when properly designed to do the work. There are two general methods of construction used in the built-up type of wheels. In one, spokes are

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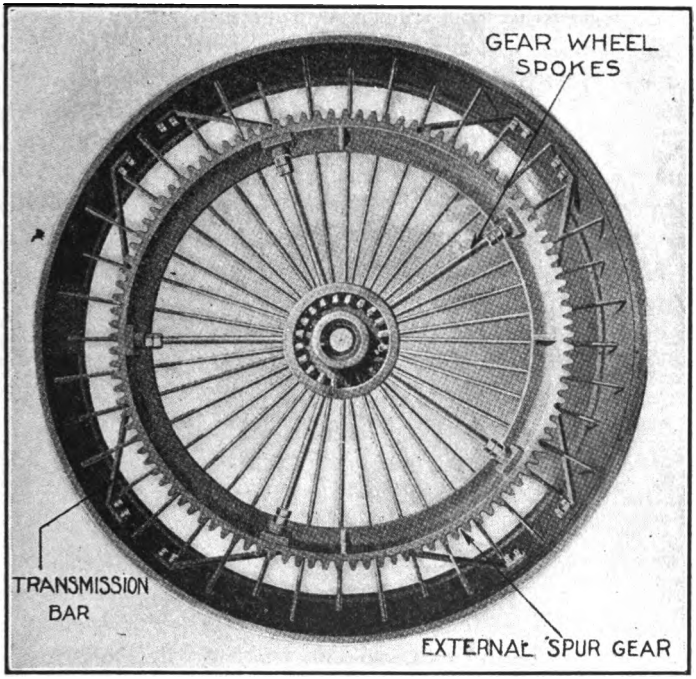

FIG. 121.—Tractor Driving Wheel Showing Method of Attaching External Spur Bull Gear to Wheel Hub and Rim.

made of flat bars which are bent over and riveted to the rim of the driver. Each spoke is attached to the hub by rivets and the weight of the engine is carried by subjecting the spokes to a compress on stress, such as obtains on practically all types of horse-drawn vehicles. The other and preferred construction is known as "the suspended type" of wheel. The spokes have round heads and pass completely through the rims and are attached to the hub in much the same manner as a wire spoke bicycle or automobile wheel.

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The weight of the tractor is therefore suspended by the spokes which are under tension instead of compression. With this method of construction there are no rivets to shear off and get loose and the suspended type of wheel is not only considerably lighter than the flat spoke type but it has greater resiliency and is superior to either the cast or flat spoke type of wheels for this reason

In order to make a large driving wheel practical when of the built-up type, it is desirable to remove all driving strains from the spokes, and in order to accomplish this the power that is applied to the large master gears is transmitted to the rim directly by connecting the driving gear to the steel plate rim member by bars of flat or round stock. The rims of the wheels must be of sufficient strength to withstand hard usage and are nearly always reinforced to prevent crimping. This reinforcement may be angle iron or channel iron hoops riveted to the inner periphery of the wheel or the rims may be specially rolled so as to have an inwardly projecting flange so that the rim will be suitably reinforced and at the same time retain the advantages of one piece construction.

A typical traction whee of the suspension spoke type is shown at Fig. 121. The master driving gear or bull gear, as it is generally called, is centered from the wheel hub by means of five rods, spaced equidistantly around its circumference and provided with adjustable members which make for accurate gear location. The actual driving strains are taken from the gear rim by means of the four brackets of flat stock which are attached to the driving gear at one point and to the rim of the wheel at two points. The wheel at Fig. 122 is practically the same in construction, except that the

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driving gear is an internal spur form and has spokes cast with the gear rim. The casting employed for the hub is also shown. The holes in the outer periphery are used to pass the spokes through while the series of slotted openings in the flanges of the hub permit the assembler to insert nuts which hold the spokes under tension and insure firm attachment to the hub.

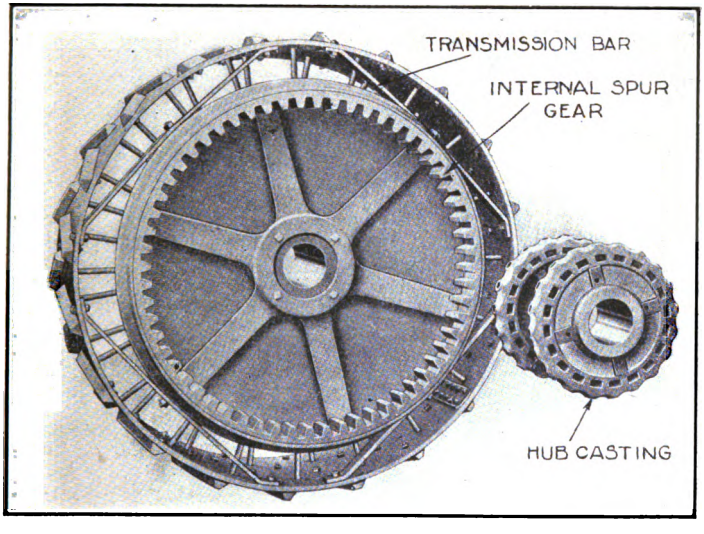

FIG. 122.—Tractor Driving Wheel and Hub Casting. Note Internal Spur Drive Gear and Method of Attaching to Hub and Rim.

On some forms of tractors it is considered desirable to reduce the shock of driving as much as possible by connecting the driving gear to the wheel rim by transmission rods and springs instead of the stiffer bars previously described. The wheel shown at Fig. 123 is a flat spoke form. The master driving gear is at-

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tached to a series of five lugs which deliver their power to the wheel rim through the medium of transmission rods, which are joined to the movable lugs only by means of helical coil springs. The drive is thus directed to the wheel rim by yielding members and the wheel is not subjected to shocks which may result from irregular or sudden power application to fixed gearing. This also permits the wheel to surmount obstacles without producing as much strain on the transmission gears

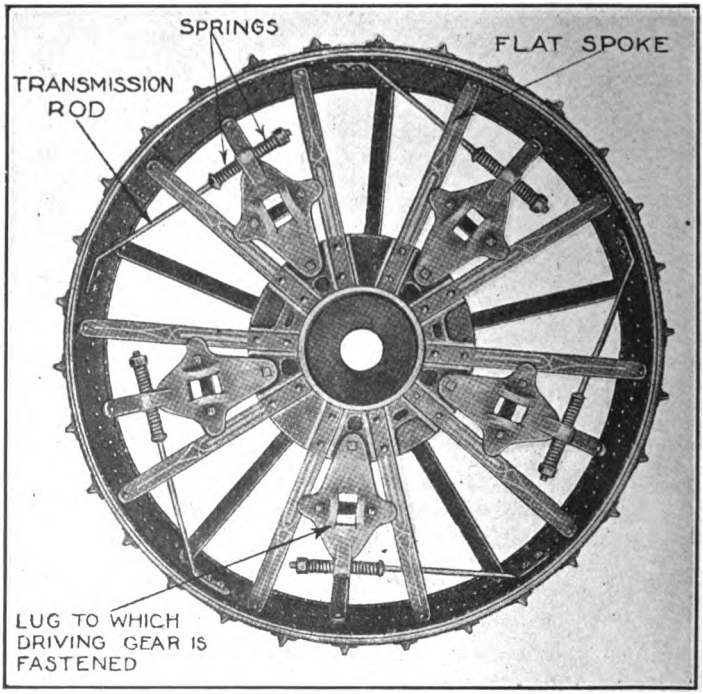

FIG. 123.—Traction Wheel of Gas Tractor With Spring Members to Remove Shocks From Driving Gears.

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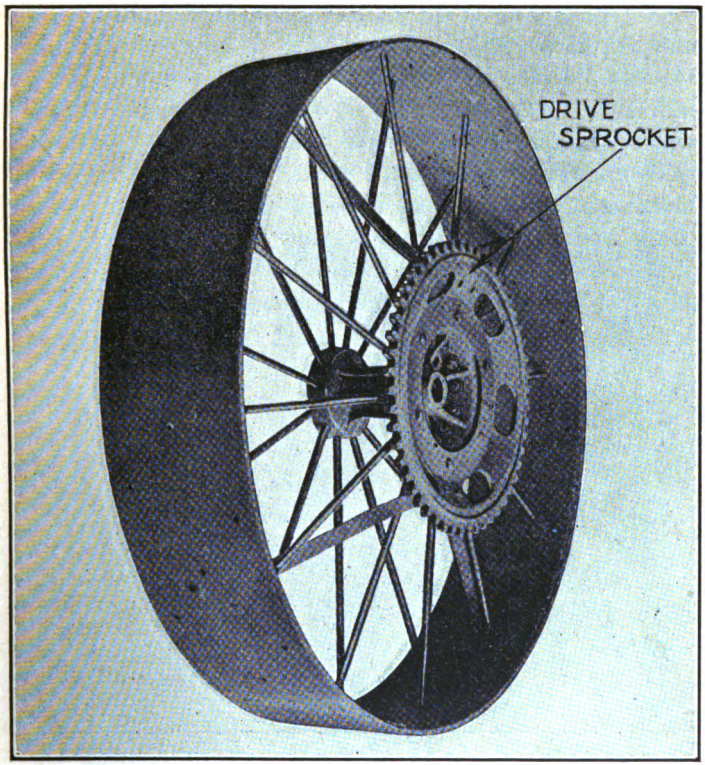

FIG. 124.—Driving Wheel of Tractor Utilizing Chain Drive.

as would obtain if the bull gear was attached directly to the wheel rim by non-yielding transmission rods.

The wheel depicted at Fig. 124 differs from those previously shown in that it is provided with a driving sprocket instead of a spur gear and must be operated through the medium of chains instead of by direct meshing of teeth, as is the case with either internal or external spur gear drive.

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A typical hub is shown in section at Fig. 125. This consists of a casting pierced with a number of holes through which the spokes extend to the rim. This hub is of steel and is lined with a bushing of bronze which is interposed between it and the steel shaft and well lubricated to take the wear. It is kept from end movement by means of a bronze thrust collar, which bears against the axle supporting bearing and the face of the hub flange. The hub is prevented from coming off by a dust collar which is pinned to the axle.

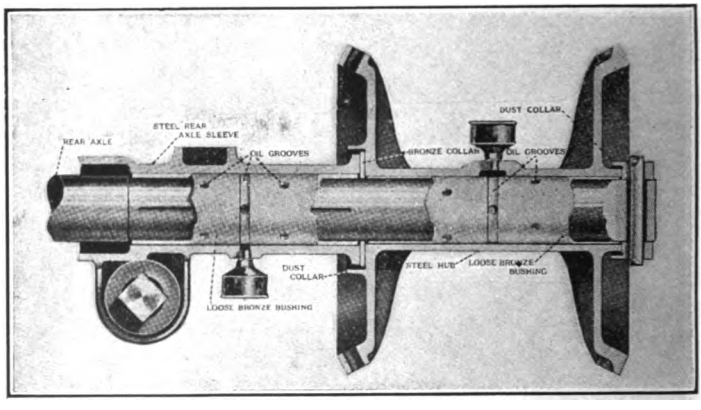

FIG. 125.—Cross Section of Hart-Parr Rear Hub Showing Wheel Bearing and Method of Lubrication.

In order to secure greater traction on soft ground than would be obtainable with a smooth steel tire the outer rims of the traction wheels are always provided with a series of projecting lugs or points which are called "grouters." These may be of pressed steel, steel castings, malleable or cast iron. They are sometimes attached parallel to the axle and at other times at an angle to facilitate self-cleaning. When grouters

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are set at an angle they are generally placed so that the rear end of one comes opposite the front of the adjacent member so the circumference of the wheel is made more continuous and jolting is eliminated on hard surfaces. Pressed steel plates may be used to form a continuous succession of corrugations which

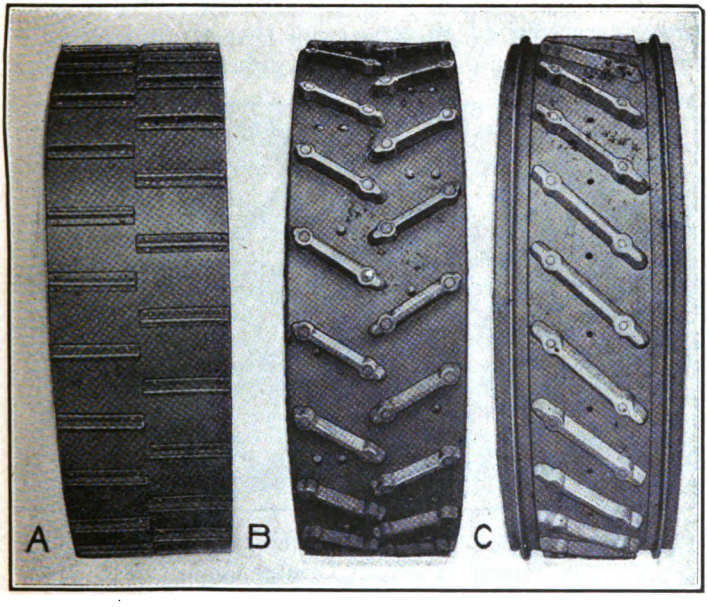

FIG. 126.—Traction Wheel Rims Showing Cleats or Grouters of Various Types Utilized to Increase Frictional Adhesion With Ground.

will extend entirely around the circumference of the wheel. It is claimed that this form of construction can pass over soft ground without tearing up the surface and at the same time it is as efficient under other conditions as the other types. Some tractor manu-

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facturers provide sharp conical pyramid shape spikes which may be removed if the tractor is to be operated over road surfaces that it is not desirable to tear up.

Various forms of grouters are shown at Fig. 126. Those outlined at **A** are merely strips cut from T section iron bar riveted to the wheel rim. This is the form usually provided on English tractors and while these prove very efficient on good roads they are not as satisfactory as the more pronounced grouters or mud lugs

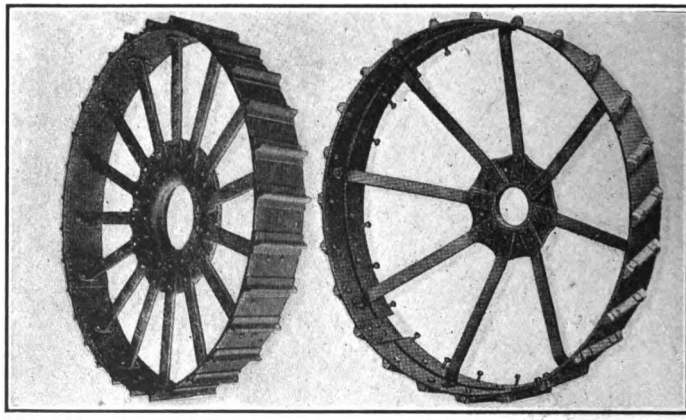

FIG. 127.—Extension Rims Designed to be Attached to Regular Traction Wheels to Obtain Greater Contact Area When Used on Soft Ground.

in general field work. The grouters shown at **B** are iron castings bolted to the rim. At **C** a combination of angularly placed grouters and external flanges to minimize lateral slip of the wheel is provided. It is sometimes desirable to provide a greater area of contact than is obtained with the regular width wheel when operating a tractor on soft ground. Extension rims, such as shown at Fig. 127, are provided in most

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cases for use in conjunction with the regular types of wheels. These extensions range from ten to fifteen inches in width and are designed so that they may be easily attached to the traction members when it is desired to increase the width of the wheels.

Action and Advantages of the Caterpillar Tread. —It is a fact that will not be questioned that a heavier load can be hauled over a smooth road than over a rough or muddy one. The locomotive, a very efficient and powerful traction engine, travels on a smooth steel

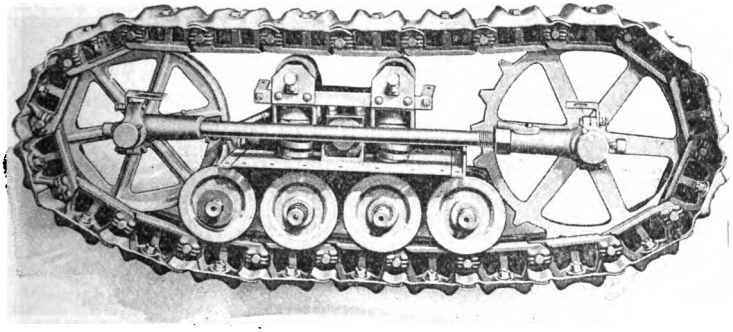

FIG. 128.—Showing Construction of Caterpillar Tread Traction Member of Holt Tractor.

track. It would not be possible to lay tracks over our highways for tractors to operate on so one tractor manufacturer obtains the advantages of the track principle and applies it to the agricultural and freighting industry by using what are known as "Caterpillar Traction Members." This tractor, which has been previously illustrated, automatically lays and travels on a smooth level steel track, strong, durable and flexible, over which it successfully negotiates ploughed fields, soft delta lands, prairies, country and mountain roads, and

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operates successfully over field and highway surfaces that are very difficult to negotiate with wheel traction engines. The Caterpillar Tread enables the engine to bridge ditches several feet in width, a feat that is not possible with the wheel forms.

By means of the track distribution of weight is effected over an area of ground the equal of which is not covered under any other than this track laying principle of construction. The increased area of contact between the traction members and the ground means better traction and increased drawbar horse-power. The side view of the Caterpillar Tractor shown at Fig. 16 indicates clearly the method of construction, while the illustration at Fig. 17 shows the tractor from another point of view. The construction of the Caterpillar traction member itself is clearly shown at Fig. 128. The construction is simple and easily understood. The track shoes, which come in contact with the ground and take the place of a tire on the ordinary wheel, are drop forged from plough steel, and are practically indestructible. The track rails are made of steel castings which have great strength and endurance. The spacing blocks which hold the pair of rails to the proper distance and with which the sprocket teeth engage to drive the track are made of manganese steel. The power is applied by steel sprocket wheels at the rear end of the machine which continually picks up the tracks, carrying them forward over the supporting rollers to blank sprockets which continually lay the tracks down and provide a path over which the engine moves.

The ordinary wheel with a 24-inch base width in order to cover an area equal to that of one 24-inch Caterpillar track would have to be 120 feet in diameter and would weigh more than fifteen tons. Obviously, this is not

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a practical construction, so the advantage the Caterpillar track offers in the matter of contact area in proportion to weight can be readily understood. Reference to the illustration at Fig. 129 serves to bring out these differences clearly, while the tabular comparison at Fig. 130 shows the claims of the manufacturers of this device and the comparison made by them between the

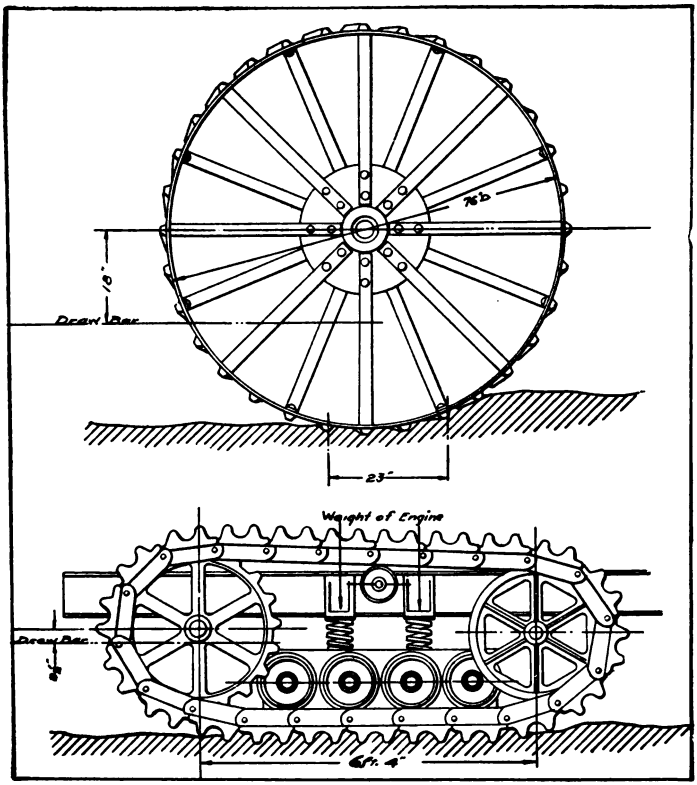

FIG. 129.—Comparison Between Wheel and Caterpillar Tread Traction Members.

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COMPARISON OF CATERPILLAR AND WHEEL TYPES OF TRACTION ENGINES.		
	CATERPILLAR	WHEEL
Rolling Friction	Quite constant under ordinary conditions	Very high in loose earth
Ground Slippage (Proportional to area of ground contact, Wt. on drivers and number of grousers in contact with ground	3000 sq. in. ground surface area.	Dependent on condition of ground. Never exceeds 300 sq. in
	Assuming weight on drivers the same - 16,500 lbs. or more	
	126 grousers in Contact	Never more than 3
	Load per sq. in. of ground surface 5.5 lbs.	40 to 90 lbs.
Faculty for Bridging uneven places	Good on account of long ground contact.	None
Weight on Front Steering Wheels	Practically constant.	Dependent on Tractive effort and grades
Tendency to pack the earth dependent upon Wt. per Sq. in. under Drivers	5.5 lbs. per Sq. in.	40 to 90 lbs per sq. in
Center of Mass above ground	About 40"	55" or more

FIG. 130.—Tabular Comparison Between Caterpillar and Wheel Types of Traction Engines.

Caterpillar Tread and the wheel form that they also manufacture. It is contended that the great bearing surface obtained by this construction ranges from 2,000 to 3,600 square inches, varying with the width of the track. Consequently the weight of the traction engine is so distributed that a pressure of but from four and one half to eight pounds per square inch is exerted against the ground which is much less than the pressure exerted by a horse.

The distribution of the weight over such a great surface eliminates the possibility of the engine becoming

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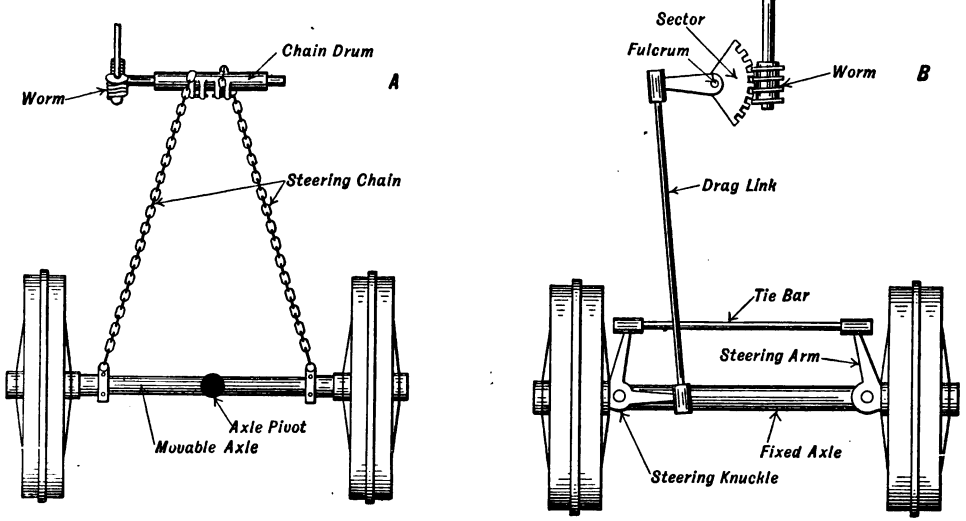

FIG. 131.—Showing Two Methods of Steering Four Wheeled Traction Engines. *A*—Tight and Loose Chain Method. *B*—Worm and Sector Gear and Ackerman Axle.

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mired where the ground is wet and soft and the tractor cannot pack the soil and injure its fertility as much as other forms which concentrate a greater amount of weight on a lesser bearing surface. The wheel trucks are spring mounted and pivot on center in order to permit the tread or track to conform with the irregularities of the road bed. Thus the weight of the engine is carried on eight small truck wheels, four on each side, which are mounted on roller bearings to reduce the friction and which roll smoothly along on the track rails like the truck wheels of a railroad locomotive. The combined width of these rails is nine inches, which is equivalent to four ordinary sixty-pound railroad rails, two of which would have ample carrying power to support the entire weight of the Caterpillar tractor.

Tractor Front Axles.—The function of the tractor front axle is more in directing the machine than in supporting much of the weight of the engine. Owing to the comparatively small diameter and width of the front wheels it is not desirable that they be called upon to take much weight. It is desirable to concentrate as much of the weight on the rear or traction members as is possible because the tractive efficiency depends upon the amount of force with which the driving members are held in contact with the ground. Then, again, if the front wheels of a tractor were called upon to carry much of the weight it would be difficult to control the engine when on soft ground. The type of front axle used will depend entirely upon the method of steering employed. It may be a one-piece axle like that of a carriage or wagon, supported by a ball and socket joint at the center which will permit it to swivel around when operated by the steering gear or move up and down under the influence of road irregularity.

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The front axles of many tractors follow automobile engineering principles and are built on the same plan as the Ackerman axle so widely used and practically universal on self-propelled road vehicles.

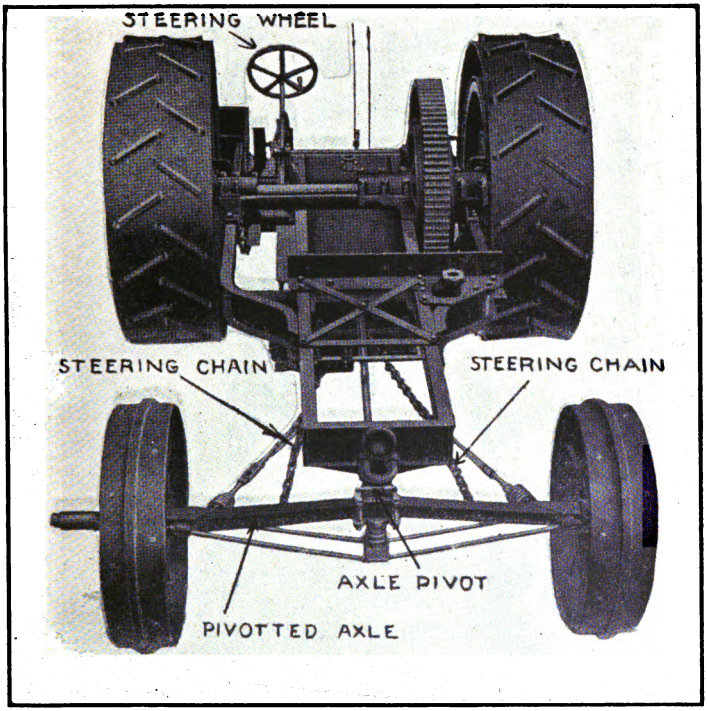

FIG. 132.—Front View of I. H. C. "Mogul" Gas Tractor Frame Showing Centrally Pivoted One Piece Axle.

How Tractors are Steered.—The common methods of steering tractors when two front wheels are employed are clearly outlined at Fig. 131. At **A** the ordinary tight and loose chain and drum construction which has received wide application on road rollers and steam

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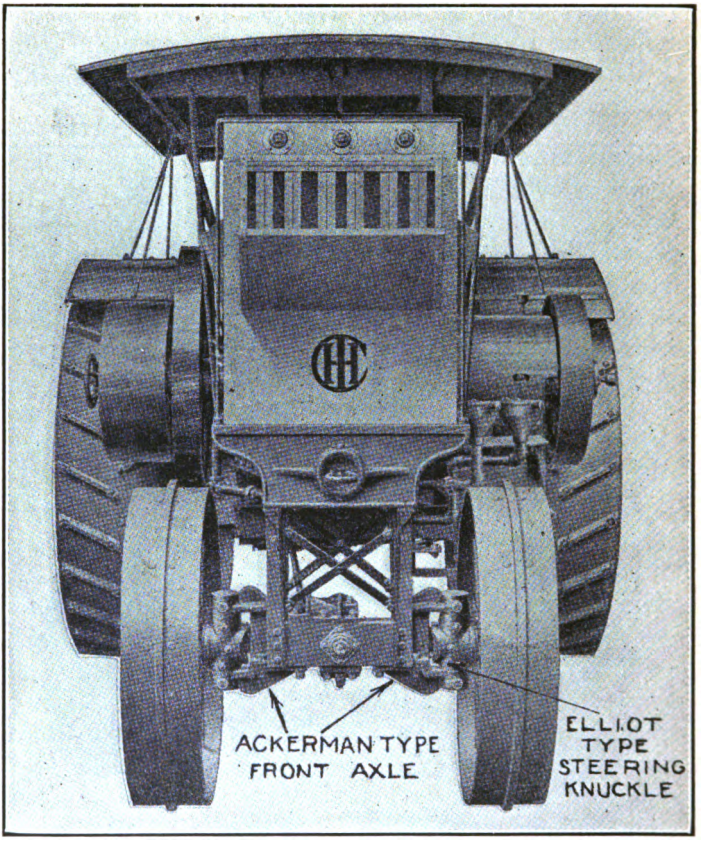

FIG. 133.—Front View of I. H. C. Tractor Using Ackerman Type Front Axle With Elliot Pattern Steering Knuckles.

traction engines is outlined. A drum is mounted across the two frame members and is operated by means of a worm and worm wheel. The chains, which run to the front axle pivoted at a central point, are so joined to the drum that when this is turned one chain winds

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up, while the other unwinds. Obviously the axle will be pulled along with the chain that is winding up and the axle and wheel assembly will assume a steering angle just as the front wheels of a horse-drawn vehicle do

The method at **B** is by the Ackerman axle. The axle is a member fixed in one direction, i. e., it cannot swing around but can move only up and down or tip from side to side under the influence of hollows or mounds on the road or field surface. The wheels are mounted on small stub axles which are attached to steering knuckles adapted to swing in yokes carried at the extremities of the axle. Steering arms extend from each knuckle or steering spindle and are joined together by a tiebar so that one wheel cannot move without producing a corresponding movement of its neighbor. One of the steering knuckles is provided with two steering arms, one of which is attached to the tiebar, while the other is joined to the steering mechanism by a drag link. The reduction in practically all cases between the handwheel and the steering members is by worm and sector gearing. The sector is fulcrumed so that it swings about a fixed point and the reciprocating motion of the steering arm the sector operates is transmitted to the steering knuckles by the drag link. The advantage of the type of steering gear shown at **B** is that it makes for more stable support than the swinging front axle does and it is also operated more easily.

The view at Fig. 132 is taken from the front end of a tractor running gear and clearly shows the application of the pivoted axle and the tight and loose chain steering gear. At Fig. 133 a heavy tractor front axle of the Ackerman type having Elliot pattern steering

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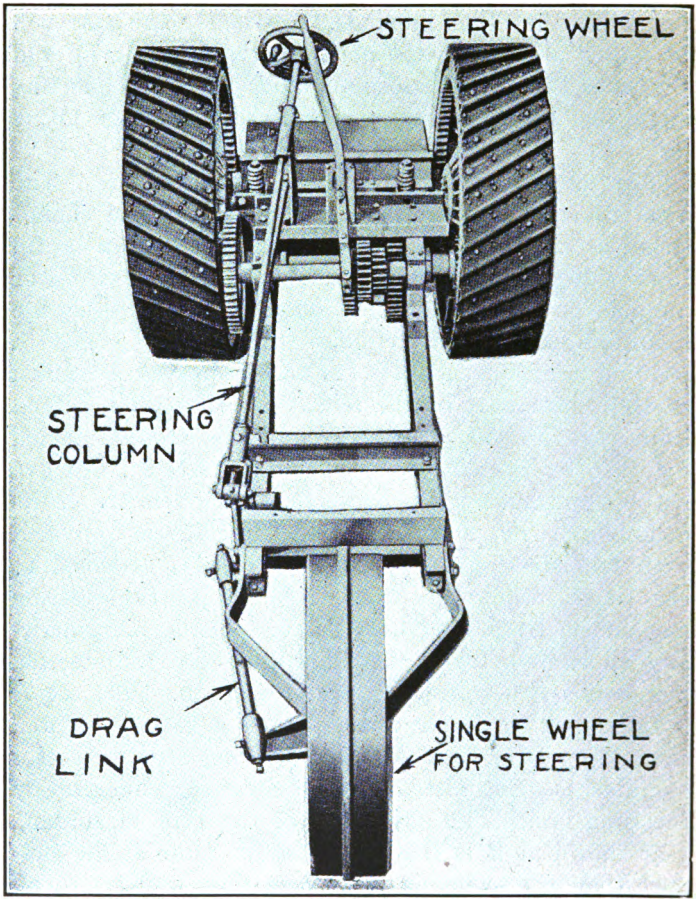

FIG. 134.—Front View of Three Wheel Hart-Parr Gas Tractor Frame Utilizing One Wheel for Steering Purposes.

knuckles to which the wheels are attached is clearly depicted. In a number of cases the tractor frame is supported by three wheels, the member carried at

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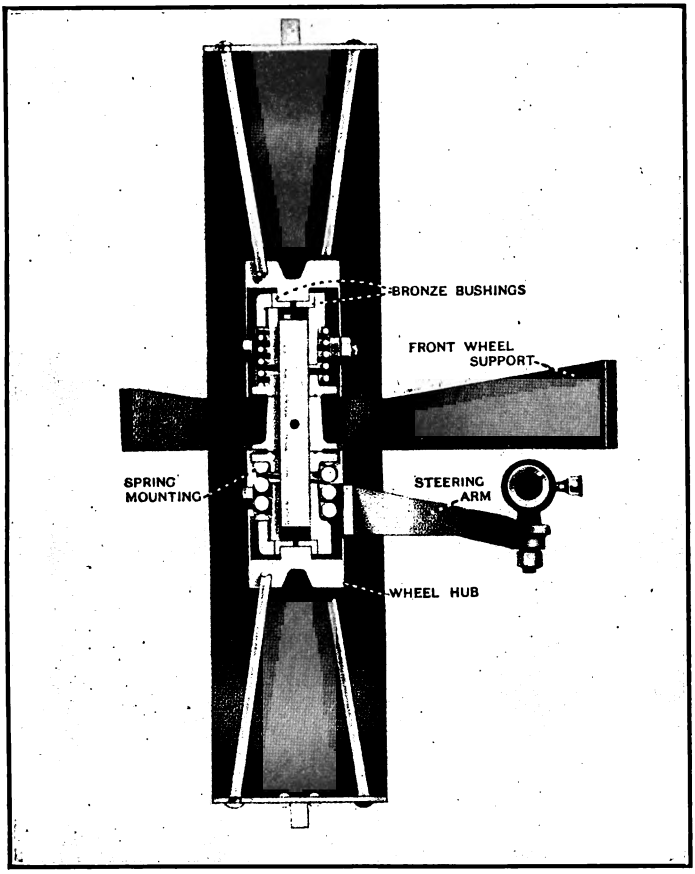

FIG. 135.—Sectional View of Front Wheel of Hart-Parr Three Wheel Tractor Showing Method of Supporting Steering Member.

the front end being utilized for steering. A frame of this pattern is shown at Fig. 134, the wheel being operated through the usual form of steering wheel by means of reduction gearing and a drag link.

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The method of supporting a single front steering wheel is clearly shown at Fig. 135. The wheel has a large hub which is provided with a bearing surface on its inner periphery which runs on two bronze bushings carried by the steering knuckle. The wheel is supported by a cross member which is attached to a bearing in which the steering knuckle pivot pin is fastened. A steering arm is attached to the wheel core and moves the wheel to the angle desired for steering.

Automatic Steering Arrangement.—In many cases it is desirable to provide means so that a tractor and plough outfit can be operated by one man without difficulty. This may be done in two ways. Either the steering or the operation of the machinery the tractor is hauling must be automatically arranged. In ploughing with the lever actuated types of engine ploughs the engine operator can attend to these if long furrows are being ploughed without difficulty if an automatic steering arrangement is used. A typical construction when applied to a tractor having a centrally pivoted one-piece axle is shown at Fig. 136, while another form, which is suitable for use when a front axle of the Ackerman type is utilized, is depicted at Fig. 136-A. The operation of these devices is not difficult to understand. As usually constructed a wheel is carried by a frame extending from the front axle which drops into the last furrow cut. If the furrow is moderately straight, this wheel will keep the tractor axle in proper position so that it can follow any slight deviations from a true course made in cutting the last furrow without any attention from the operator.

At Fig. 136 it will be apparent that when a front wheel is carried at the extremity or apex of the triangular support joining it to the axle, which forms the base,

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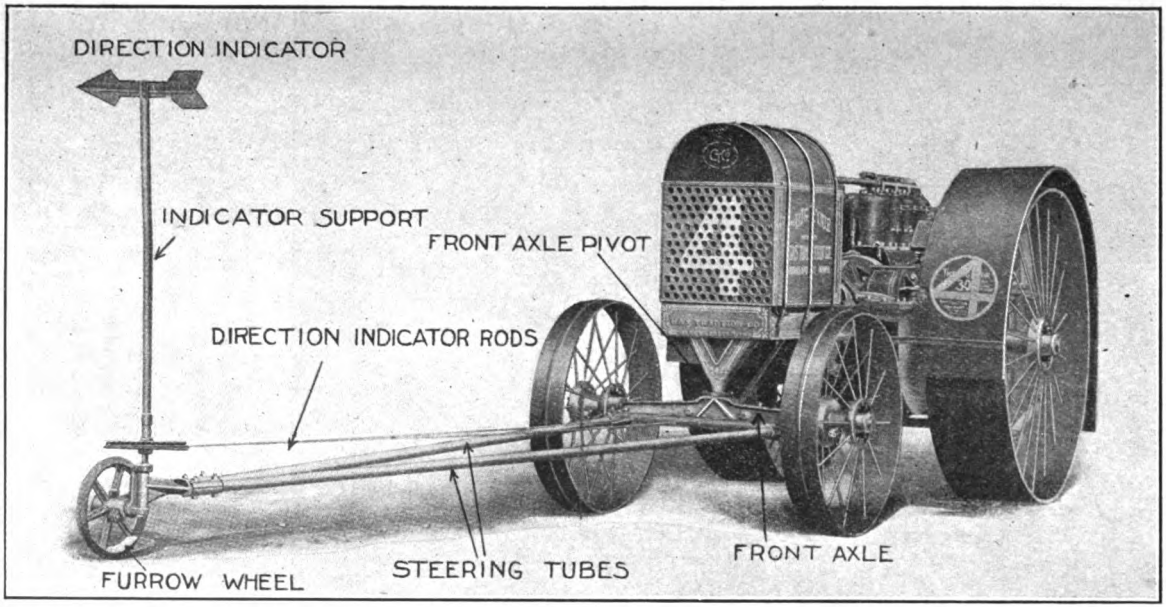

FIG. 136.—Outlining Application of Automatic Steering Arrangement to "Big 4-30" Gas Tractor.

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any movement of the wheel will be transferred back to the front axle. An arrow carried at the end of a standard so that it can be conveniently glanced at by the operator from time to time serves as a direction indicator and a guide by which the course of the tractor or any deviation from a correct line of travel will be

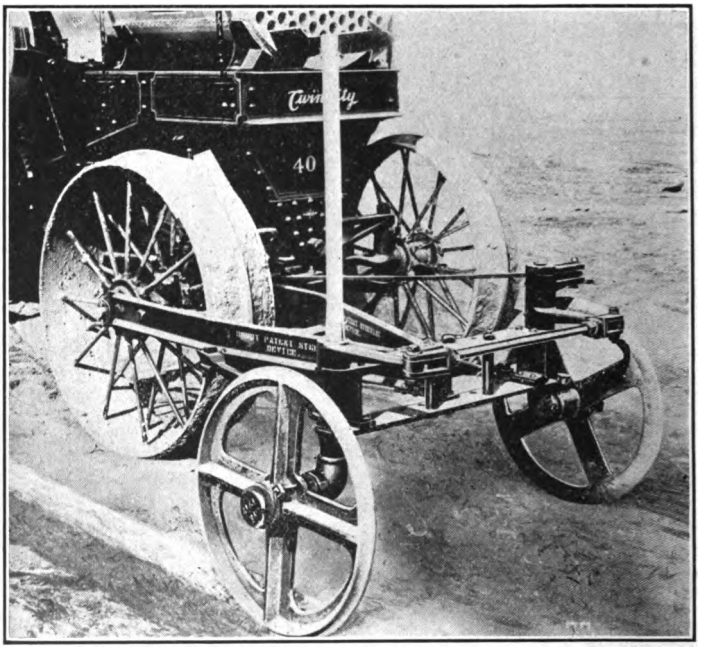

FIG. 136A.—The Cuddy Automatic Steering Device Applied to Ackerman Type Front Axle.

readily ascertained. In the device shown at Fig. 136-A the action is somewhat similar to that previously described, except that two wheels are used and a system of leverage is employed to change the direction of

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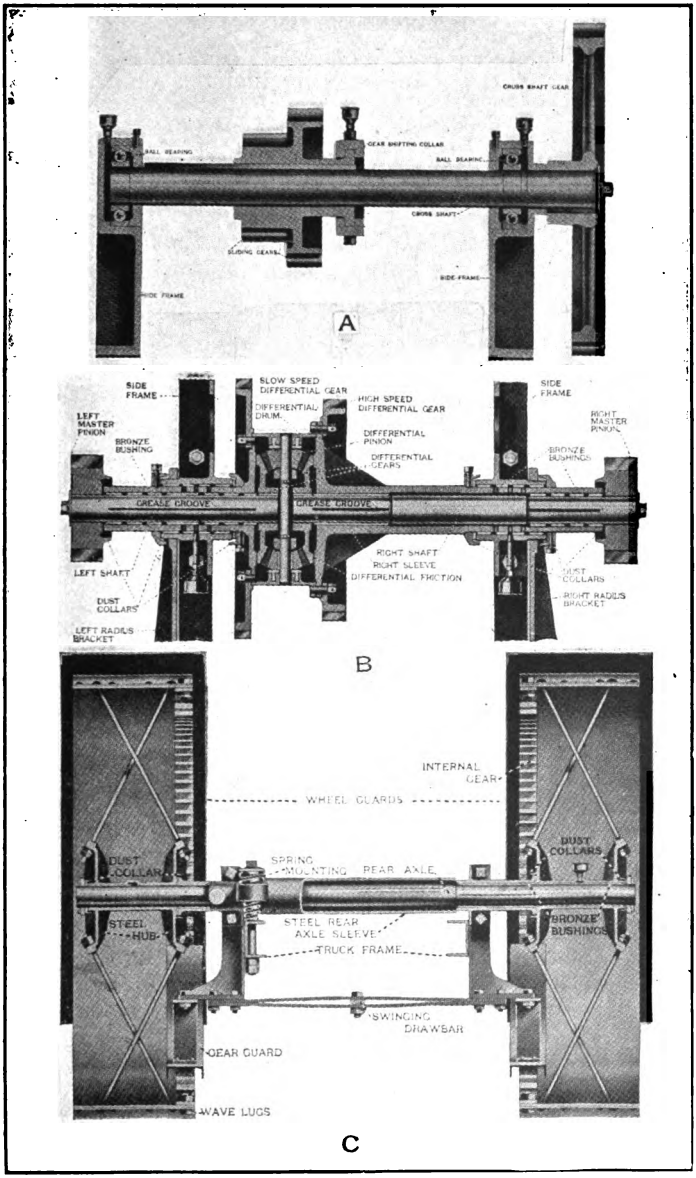

FIG. 137.—Showing Important Members of Conventional Power Transmission System.

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movement of the main steering member on the front axle.

Methods of Final Drive.—One of the important problems that the tractor designer is called upon to solve is that of power transmission from the motor to the rear wheels. It is imperative that this be accomplished with as little loss of energy as possible because the power loss through friction of gearing is not available at the drawbar. Unfortunately, it is necessary to employ a large gear reduction between the engine and the tractor rear wheels and this can only be accomplished by using intermediate gearing, which is interposed between the bull gears on the wheels and the crankshaft of the motor. The efficiency of the transmission system depends largely upon the number of gears used, whether these are smoothly finished or merely rough cast members and whether they are suitably protected from the abrading action of the dirt and grit present in field work.

Well cut steel gearing, properly housed in a dust-proof and oil-tight casing can be kept lubricated and therefore maintained to a high degree of efficiency. This is more easily accomplished with countershaft or intermediate gearing than with the main bull pinions and gears. It is necessary in most constructions that these be exposed on account of the difficulty which obtains in incasing them properly. Several tractors are built, however, in which all gearing is protected from grit and kept running in a bath of lubricant Obviously the wear will be less on gearing of this nature.

The Conventional Method.—The conventional arrangement of driving gearing with the various parts separated in order that their construction may be clearly ascertained is shown at Fig. 137. The power of the

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engine is first directed to the cross shaft shown at A This is mounted on ball bearings of the annular pattern and carries at one extremity a large spur gear which meshes with a pinion on the engine crankshaft. A sliding member composed of two gears is adapted to be moved back and forth on this cross shaft by a

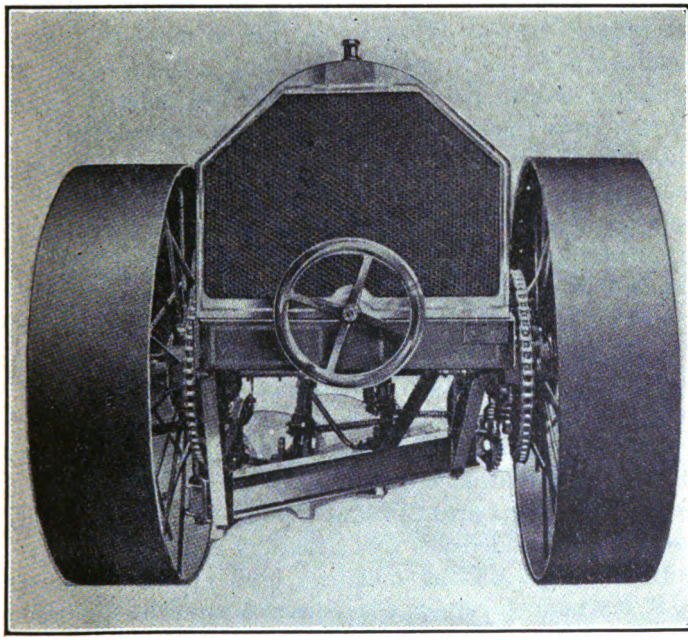

FIG. 138.—Front View of Hackney Gas Tractor Which has Traction Members at Front End and Single Rear Wheel for Steering.

gear shifting collar operated through a hand lever forming part of the control system. These sliding gears must turn with the cross shaft because they are kept from rotating independently of it by a substantial

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key which, however, does not limit their lateral motion. Immediately back of this cross shaft to which the power from the engine is first delivered, another countershaft assembly, which is depicted at **B**, is mounted This is spaced in such a way that the sliding gears on the main shaft of the transmission may be moved to engage two gears bolted to the differential gear casing. When the largest gear on the cross shaft is in mesh with the smallest gear on the differential case a high speed is obtained while the engagement of the smaller gear on the cross shaft with the larger gear attached to the differential drum gives a reduction in speed. The arrangement of the differential gear interior is just the same as has been previously described, the balancing mechanism being of the bevel gear and pinion type. As is true of all differential cross shafts the right and left master pinions, which engage the bull gears on the rear wheels, are driven by independent shafts from the differential gears. The rear axle is of the usual dead pattern and is depicted at **C**. Large internal spur gears are attached to the wheel rims and are driven from the differential cross shaft by the master pinions.

Use of Chains and Sprockets.—The driving method previously considered is that generally followed because with the large driving members used on gas tractors it is desirable to apply the power as near to the rim as possible. In some form of tractors the drive from the differential cross shaft to the traction members is by chains and sprockets such as are used widely in automobile engineering practice. This permits one to locate the differential gear cross shaft at any convenient point in the frame as the drive may be through chains of any length within reasonable limits. The view at Fig. 138 is that of the front end of the Hackney auto

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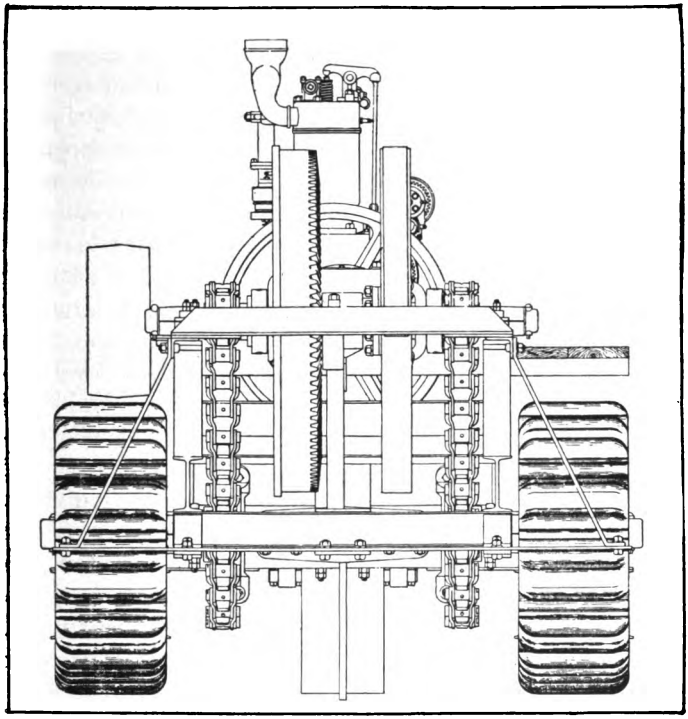

FIG. 139.—Rear View of Holt Caterpillar Tractor Showing Chain Drive to Traction Members From Cross Shaft.

plough which is unconventional in construction inasmuch as the front wheels are employed as traction members while a single rear wheel is utilized for steering purposes. This method of drive makes it possible to place the engine directly over the wheels as shown at Fig. 13 (Chapter I) and carry the differential cross shaft at a point about mid-way on the frame. At Fig. 139 the driving chains which are utilized to take the power of the engine from the cross shaft mounted above the

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rear axle of the Holt Caterpillar Tractor to the track-laying sprockets are clearly outlined.

Live Axle Forms.—One of the most popular types of axles used in automobile practice is termed "the full floating" live axle. In this construction the wheels are driven by means of shafts attached to them by some form of positive clutch while they themselves revolve on independent bearings carried by the housings which inclose the axle shaft. The differential gearing is always a part of an axle of this pattern and is mounted at the center in a case made to receive it and the shafts which drive the wheels are attached to the bevel differential gears in just the same manner as is employed on a differential cross shaft. This method of axle construction is not as satisfactory for tractor use as it is in its automobile applications, first, because it is difficult to obtain the desired gear reduction by the single pair of gears usually employed in driving the differential gear case, and second, because the power to turn the wheel is applied at its center instead of near the rim, which places severe torsional stresses or twisting strains on driving shafts when used in connection with large diameter wheels.

A number of tractor manufacturers are experimenting with this form of axle but in order to use it have been forced to reduce the size of the driving members which makes this form of construction more suitable for combined motor trucks and tractors than for the regular pattern traction engines used generally in field work. The differential drum on the automobile live axle is usually driven by a pair of bevel gears, the desired reduction ratio of 2½ or 3 to 1 being easily obtained. In order to provide the low ratios of drive needed between the engine and the rear wheels of gas tractors

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it would not be possible to employ bevel gears carried directly in the differential housing. The use of worm gearing, however, enables the designer to employ but a single pair of reduction gears in the rear axle though a set of intermediate gearing is necessary to provide a partial reduction of speed before the power is directed to the worm gear of the axle.

The construction of a worm gear driving assembly is clearly shown at Fig. 140. The worm gear is attached

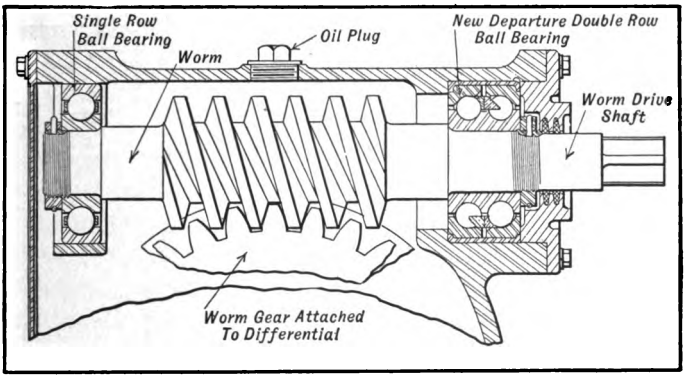

FIG. 140.—Sectional View of Worm Drive Gearing Used in Connection With Live Rear Axle.

to the differential casing and is revolved by means of the worm mounted above it and connected to the speed reducing cross shaft back of the engine. In order to reduce friction to a minimum the worm is mounted on New Departure ball bearings of the single and double row types. The end thrust of the worm is taken by a large double row bearing which is clamped to the shaft and housing in such a manner that it is restrained from lateral movement and is thus able to resist thrust in either direction and radially applied

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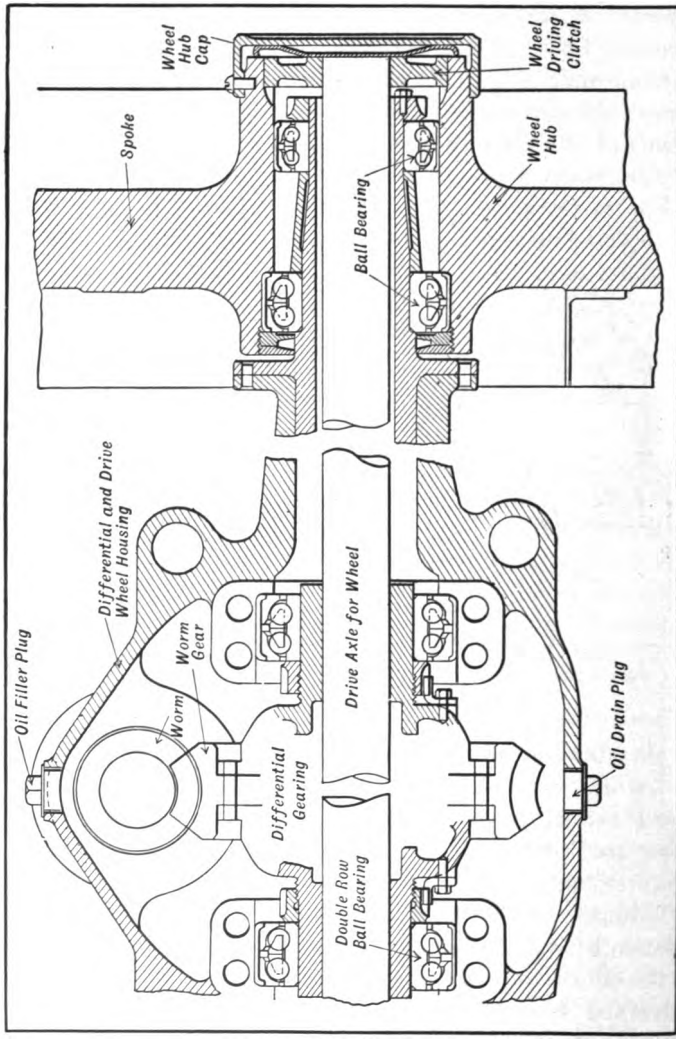

FIG. 141.—Sectional View of Half of Rear Axle of Live Type Used in Connection With Worm Gear Final Drive.

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loads as well. The single row ball bearing of the conventional annular pattern has a floating outer race, i. e., that member can move back and forth to some extent should the worm shaft expand due to heating while in operation. Gearing of this character is carried in an oil-tight container and as the differential casing may be filled with lubricant through the oil filler plug at the top of the case the gearing will run with minimum depreciation and maximum efficiency.

The view at Fig. 141 is a section through half of a worm gear driven live axle. The differential assembly is mounted on large double row bearings which locate the worm gear accurately in the center of the driving worm, a condition necessary to secure efficient driving. The rear wheels are carried by two double row ball bearings the inner members of which are clamped to and supported by the tube or housing serving to inclose the driving alxe. The drive shaft turns the wheel by means of a positive clutch attached to the end of the axle shaft and fitting into suitable depressions in the interior periphery of the wheel hub. An advantage of this method of construction is that the differential gear and driving axles may be removed if necessary without taking off the wheels. Owing to the expense of building and the fact that this method of axle construction is not adapted for use with the extremely large diameter driving members ordinarily employed on gas tractors it is obvious that the systems of drive in which the power is applied to the rim of the wheel directly instead of through the medium of the spokes and hub will continue to be most popular and generally satisfactory.

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CHAPTER IX.

DRIVING AND HOUSING THE TRACTION ENGINE.

How to Start Traction Engines—How to Start Tractor—Typical Tractor Control Systems—Advice on Tractor Operation—Housing the Tractor—Combined Tractor House and Farm Workshop—Fuel Storage Methods—Tools and Equipment for Care of Tractor.

How to Start Traction Engines.—As a rule before shipment from the factory, all of the reputable makes of gas tractors are thoroughly tested with and without load to make sure that all parts are functioning properly. This includes tests of the motor on the block, running the tractor on a special testing track around the works and after the machine has been in use for some time, determining the power capacity of the motor to ascertain if it approximates the standard established by means of a brake test and determining the tractive or pulling power by some form of dynamometer test. Therefore, the tractor purchaser receives a machine that has been carefully tested and that should start without difficulty if the proper steps are taken.

The most important thing to do before endeavoring to start the engine is to see that the fuel and water containers are full and that all the electric wiring is properly connected. All mechanical oilers should be filled with the proper lubricant and if a constant level splash system is employed enough oil to insure thorough lubrication should be put into the crank case. The

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open gears should be well covered with grease and all grease cups should be screwed down to make sure that all bearing surfaces fed by these members are receiving the proper supply of lubricant. Generally one or two quarts of oil will be sufficient in the crank case and nothing but the best cylinder oil should be used for this purpose. If there is too much oil in the engine, clouds of white smoke will issue from the exhaust pipe, so a certain amount can be drained from the engine case by means of petcock or drain plug provided for the purpose. In starting a new engine it would be well to remember that surplus oil will do no harm and that plenty of oil is much cheaper than repairs. When the engine is new and all bearing parts are still stiff, copious lubrication is one of the surest methods of obtaining a smooth running machine.

Before attempting to start the engine one should become familiar with the various control levers provided both for controlling the speed of the motor and for handling the various clutches. The first point to make sure about is that the master clutch handle is set in a neutral position, i. e., with the clutch released. This will disconnect the engine from the transmission and will permit the power plant to run independently of the rear wheels. The spark advance lever is placed in the full retarded or late position, the lever that controls the throttle of the carburetor is set so this member will open the throttle slightly and the engine may be primed by pouring a little gasoline in each of the cylinders through the priming cups or petcocks, if these are provided. The switch is placed on the side of the coil marked "battery" if a double ignition system is provided. The engine is turned over, either by means of a starting handle attached to the crankshaft or by

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rocking the flywheel on those types of tractors that are not provided with a starting crank.

After the engine crankshaft has been turned over two or three times a sharp hiss will be heard at one of the priming cocks accompanied by a sheet of flame. The priming cocks are then closed and the engine crankshaft is given a brisk turn until one of the pistons passes

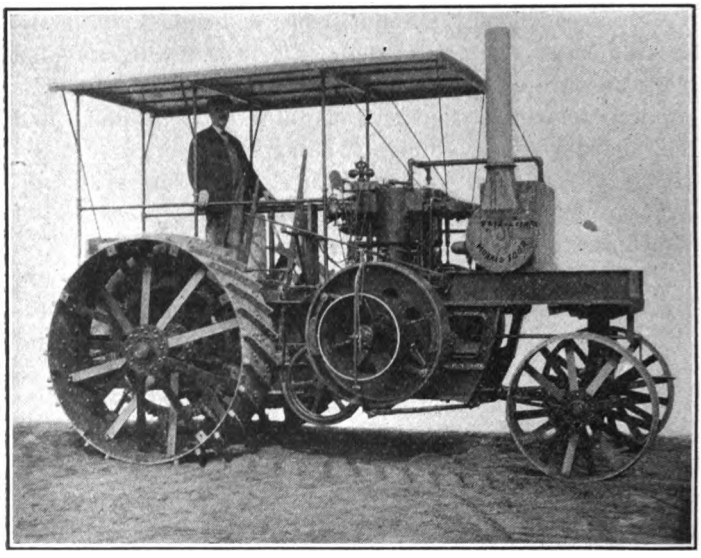

FIG. 142.—Side View of Morris Tractor Showing Operator's Platform and Control Levers.

its compression and ignition point. The engine should start off at once if everything is right. After the power plant has started and is running at the proper speed, throw the switch lever to the side of the switch marked "magneto" but keep the throttle of the carburetor nearly closed until ready to start the tractor. This

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will prevent the engine from racing and the crankshaft will turn at a comparatively low speed. By referring to the view of the tractor shown at Fig. 142, the location of the operator's platform and control levers are easily determined. In this machine, it is necessary to start the engine by rocking the large flywheel or turning it over until the pistons have drawn in a charge of gas and it has been compressed ready for ignition.

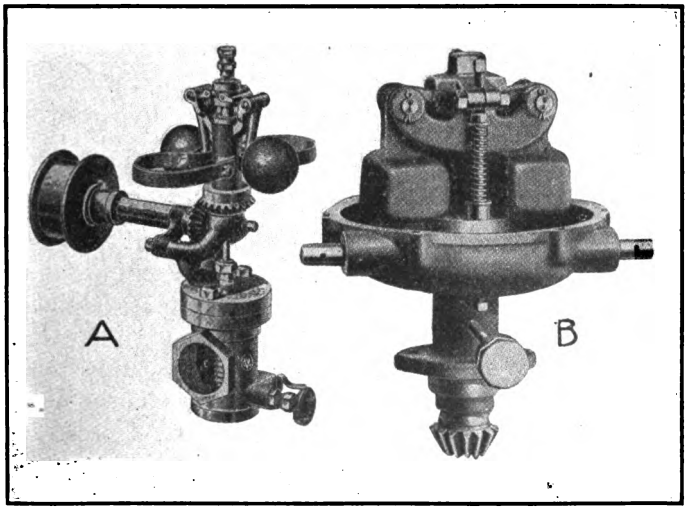

FIG. 143.—Governors of the Centrifugal Type Form Important Part of Tractor Power Plant Control System.

While most tractor power plants are provided with automatic centrifugal governors, such as shown at Fig. 143, to keep the engine from racing even if the throttle lever is open, they are set so that the engine speed will be higher than is desirable when running light. These governors are made in two forms, the

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type generally used being shown in illustration. The tractor power plant may be controlled by a throttling governor or by a hit and miss system which is employed when engines of the stationary type are utilized as power plants. The centrifugal governor is the most popular where the engine is supplied with gas by a carburetor provided with a throttle so that the amount of vapor supplied the cylinders may be regulated. The principle of the centrifuga governor is easily understood When the speed of the engine increases to a point where it is desirable to reduce it the weights attached to the governor arms fly out on account of centrifugal force and close the throttle, this slowing up the engine.

The governor shown at **A** (Fig. 143) forms part of the mixing or vaporizing valve that supplies mixture to the cylinders. It is driven by means of a small, flat belt running from the engine crankshaft to a pulley on the governor. The power from the horizontal shaft is transmitted to the vertical revolving member that carries the governor weight and spring assembly by a pair of small miter gears. The governor shown at **B** is similar in construction, except that it is provided with a case, the cover of which is removed to outline construction of interior mechanism. The tendency of the weights to fly out is changed to a reciprocating motion of small plunger rod members which oscillate the shaft carried at the base of the casing to which the throttle lever is attached. This form of governor is driven directly by means of a bevel gearing carried inside of the engine base. In some tractors the control system is so arranged that the governor may be cut out at will and the power plant controlled solely by the throttle lever, if it is desired to augment the speed

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of the engine beyond that point to which the governor is set.

As a rule it is not difficult to start a multiple cylinder engine by the hand starting crank provided, or by rocking the flywheel. In some cases where a one or two cylinder engine of large capacity is utilized it is difficult to start these by hand unless conditions are exceptionally favorable. The difficulty usually encountered in setting in

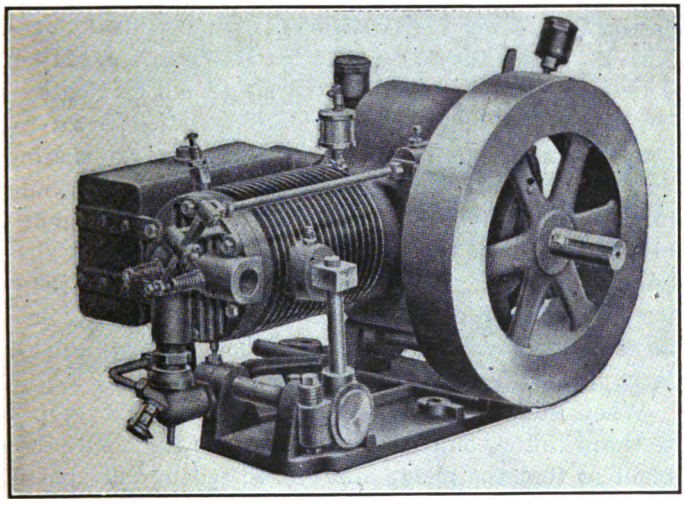

FIG. 144.—Small Engine Used to Start Large Power Plant of I. H. C. "Mogul" Tractor.

motion a large engine, especially in cold weather, when the oil in the cylinder has congealed, is ingeniously overcome on the I. H. C. 45 horse-power Mogul tractor by providing a 1 horse-power engine of the air cooled type to turn the crankshaft of the power plant over. This little engine, which is illustrated at Fig. 144, relieves the operator of all labor of revolving the heavy fly-

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wheel by hand against partial compression that is necessary on some large tractors.

This starting engine is a complete little power plant in itself and is equipped with its own gasoline tank and battery box. It is an air cooled motor of the four-cycle type with an inclosed crankcase. A jump spark ignition system composed of batteries and induction coil is provided while the gasoline tank holds one gallon and is mounted on brackets extending from the cylinder casting. A small friction wheel 4½ inches in diameter with a 5-inch face is keyed to the crankshaft extension. The engine crankcase is hinged on a shaft carried by a base casting while the cylinder is steadied by a rod attached to the engine base by an eccentric bearing. This can be operated by a hand lever so the cylinder may be tilted a short distance and the friction pulley brought to bear against the tractor engine flywheel outer periphery. The engine is clamped to the tractor frame with four quickly detachable fasteners and may be easily removed and used for other work around the farm if the tractor is not in use.

When starting the larger engine, the first step is to throw in the compression relief cam of the main power plant so that the piston will be resisted by only partial compression. The small starting engine is put into operation and allowed to run free for a minute or two till it attains sufficient speed to develop full power. When this has been done, the lever rotating the eccentric bearing on the starting engine is pulled up till the friction pulley is pressed against the large engine flywheel. Owing to the difference in diameter between the flywheel and the small friction pulley the starting engine rotates the large crankshaft at sufficient speed for starting even if the large engine does not operate

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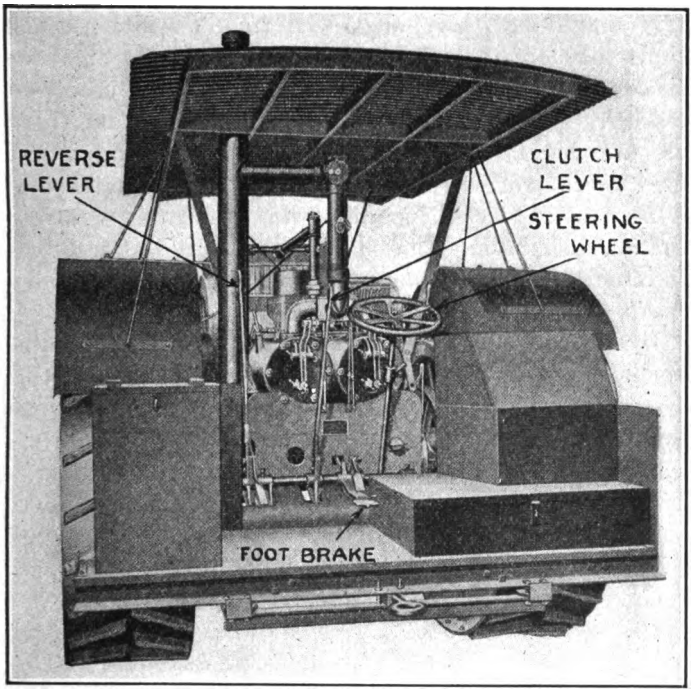

FIG. 145.—Rear View of I. H. C. Tractor Showing Control Levers and Operator's Platform.

easily. When the large engine starts, the compression relief cam is thrown out so that the piston gets the benefit of full compression and the small starting engine is tilted back and stopped.

How to Start Tractor.—After the engine has been started and has run long enough so that it is thoroughly warmed up and operating efficiently the next step is to start the traction engine itself. The type of transmission employed will determine the number of levers used to control the various speeds and forward and

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reverse motion. A one speed tractor will be much simpler to operate than a form having a two or three speed gear box. The control platform of a one speed tractor is shown at Fig. 145. It will be seen that there are two hand levers, a foot pedal and a hand wheel used to control the machine. One of the hand levers is used as a reverse member, while the other controls the master clutch. The hand wheel is utilized to move the front axle for steering purposes and the pedal applies the brake when it is desired to stop.

If the tractor is to be run in a forward direction the reverse lever is set in the notch corresponding to the "go ahead" position. The master clutch has been disconnected before the engine started and for this reason the reverse lever can be moved as desired without producing any movement of the tractor. The point should be emphasized that in no case should a reverse lever be moved without the master clutch being disengaged. When ready for the load, the throttle is opened and the spark lever is advanced, this allowing the engine to run at a speed where it will develop its power. The master clutch lever is then pushed forward or pulled back (depending upon the design) so the clutch is engaged very slowly and gradually. When the tractor has attained a certain amount of momentum, the clutch control lever may be pushed to its extreme "on" position after which it needs no further attention until it is desired to stop the tractor. The operator need only be concerned with directing the machine by means of the steering gear. If the machine is running too fast the engine speed may be reduced by closing the throttle, whereas if it is not running fast enough its speed may be augmented by opening the throttle and supplying more gas to the engine.

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To stop a tractor the first step is to close the throttle, throw out the clutch, retard the spark lever and apply the foot brake. If the stop is to be a lengthy one, the engine may be put out of operation by throwing off the ignition switch and closing the gasoline valve at the tank. The clutch lever should always be kept in the "off" position unless the reverse lever is provided

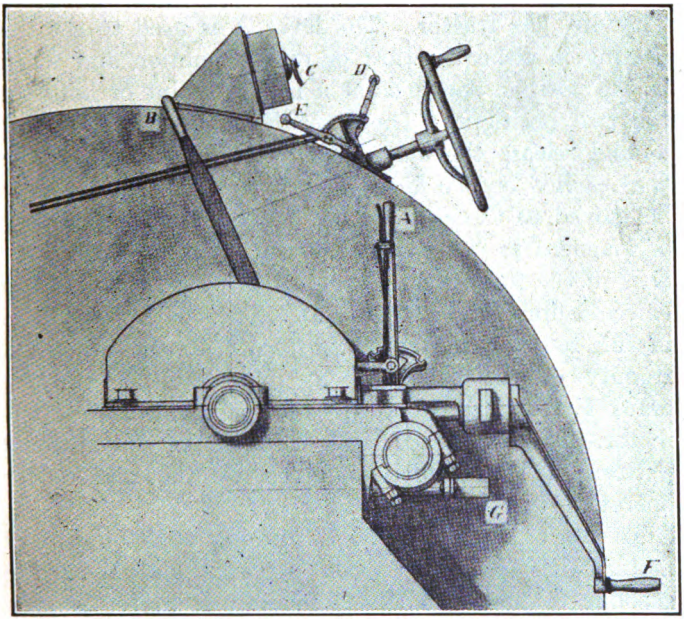

FIG. 146.—Control Levers and Starting Crank of "Twin City 40" Gas Tractor.

with a "neutral" notch, in which position it is not connected to either forward or reverse drive gears and then the master clutch may be let in if desired. It is not desirable to leave the clutch in if the tractor is to

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make a stop of any moment because considerable strain may be present in the parts of the clutch actuating mechanism which had better be released.

Typical Tractor Control Systems.—In order to enable the reader to understand the functions of the various control levers thoroughly a number of control systems of typical tractors are outlined at Figs. 146, 147 and 148. That at Fig. 146 forms part of the "Twin City 40" gas tractor. The lever **A** is used to set the gearing in either forward or reverse motion and when in the position shown is at a neutral point or between the two positions. The lever **B** is utilized to throw in and release the master clutch. The switch handle **C** is carried on the face of the induction coil and may be moved to the right or left to couple either battery or magneto to the ignition system. The throttle lever **D** is in the full open position when pulled back to the extreme limit of the quadrant. The spark lever **E** is in full retard position when thrown to the other extremity of the quadrant, as indicated. A starting crank **F** is utilized to turn over the crankshaft of the motor. Steering is by hand wheel of the conventional pattern. The instructions given by the makers for operating this tractor follow:

To Start Motor: 1.—Fill priming cups on top of motor with gasoline. Open petcocks and allow the gasoline to flow into the cylinders. If motor is very cold two or three injections of fuel may be required, while if motor is very warm, very little gasoline and often no priming is necessary.

2.—Close priming cocks and open relief cocks on side of motor.

3.—Referring to Fig. 146, use the following directions for starting motor and engaging traction: Place lever **A**

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in the central notch of the quadrant, throw in the clutch with lever **B** which is done by pushing it forward. Retard the ignition spark by throwing lever **E** forward as shown in the illustration. Open the throttle by moving lever **D** backward, as indicated Throw the switch lever **C** in contact with point marked "B" for batteries. Turn over engine crankshaft with starting handle **F** As soon as the motor starts close the relief cocks, throw out the clutch with lever **B** and stop the clutch shaft by bearing down on the brake pedal **G**. Throw the switch lever **C** onto side of switch marked "M" which is the magneto side and advance the spark with lever **E** by pul ing it backward.

To Engage Traction: For traveling forward move the lever **A** into rear notch of the quadrant; for reverse motion push it forward into the other notch. Never move lever **A** when clutch is running at high speed. If this lever cannot be moved from neutral to either side readily, revolve the clutch shaft very slowly by barely engaging ever **B** and keep one foot on brake pedal **G** to prevent rapid movement of clutch. Always engage lever **B** gradually, as engaging the master clutch too quickly will stall the motor or impose severe strains in the driving gears. A gas tractor is a heavy mass of metal and should be put in motion very slowly, the clutch being allowed to slip until sufficient momentum has been attained so that clutch may be fully engaged without shock. Control speed by spark and throttle levers.

The control system outlined at Fig. 147 is utilized on the Holt Caterpillar tractor and the same instructions for starting the engine previously given will apply in this case as well. The engine speed is regulated by the usual form of spark and throttle levers mounted

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on a quadrant, just forward of the steering wheel. Four clutch levers are provided. The one nearest the steering wheel is used to throw the master clutch in the engine flywheel on or off as desired. A reverse lever which can be set at either neutral position as indicated or for forward or reverse motion is provided

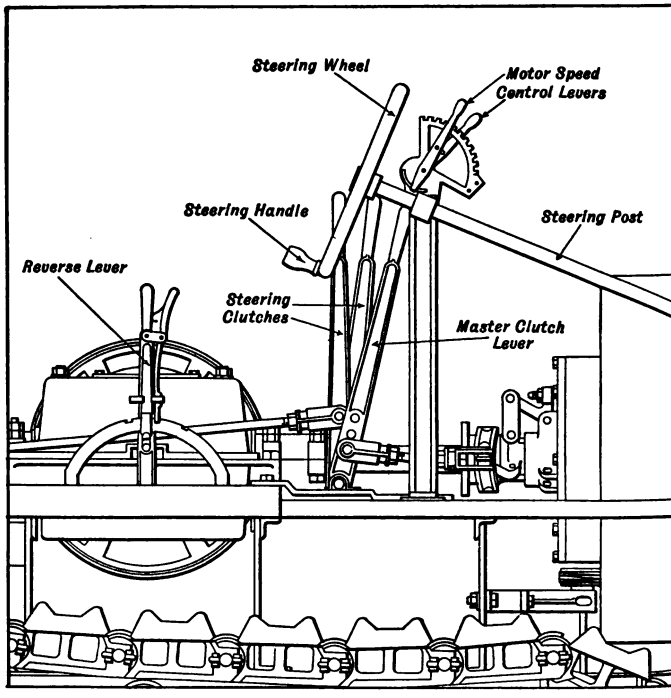

FIG. 147.—Control System of Holt Caterpillar Tractor Showing Important Elements.

convenient to the operator and back of the master clutch lever. The other two hand levers, which are placed alongside of the master clutch control lever, are utilized

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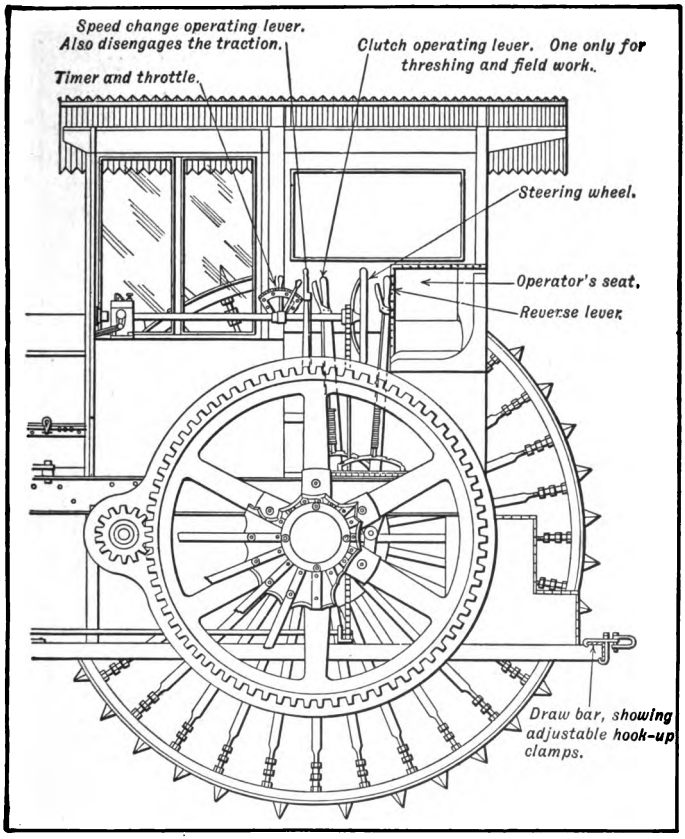
Speed change operating lever.
Also disengages the traction.
Clutch operating lever. One only for threshing and field work.
Timer and throttle.
Steering wheel.
Operator's seat.
Reverse lever
Draw bar, showing adjustable hook-up clamps.

FIG. 148.—Operator's Cab of Pioneer Gas Tractor With Important Parts of Control System Indicated.

to operate clutches necessary for steering with a Caterpillar Tread.

Steering the tractor is accomplished by releasing the friction clutch which drives the caterpillar traction member that is on the inside of the circle when making

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a turn, in connection with the usual form of hand wheel. With this form of traction member, steering by the front wheel accomplishes but little unless the steering clutch is disengaged to correspond with the direction one wishes to turn. After disengaging the inside friction lever the degree of turning depends on the angle of the front wheel. The mode of procedure in steering around a corner is as follows: When about to make a turn, disengage the clutch lever that controls the friction clutch driving the traction member that is to be on the inside of the circle first, then turn the front wheel and as the curve is made straighten the front wheel and engage the friction clutch that has been released when the tractor is again headed in a straight line The control of this form of tractor is not radically different from the wheel form except that care must be taken to always release one of the steering clutches to provide a certain differential action as no differential gear is fitted.

The control group, which is inside of the operator's cab of the Pioneer gas tractor, is outlined at Fig. 148. In this, the motor speed is regulated by the usual spark and throttle levers mounted on a quadrant forward of the steering wheel. Three hand levers are provided. One is the reverse lever, operating on a notched segment, so that it may be set either in neutral, forward or reverse positions. The other large lever provided with a latch is a clutch operating lever while the changes of speed are obtained by moving a third hand lever which shifts the sliding gears of the gearset. Steering is by the conventional form of hand wheel. This tractor is distinctive in that the cab is entirely inclosed to protect the operator from the elements and that a comfortable upholstered seat is provided for him. The general

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rules that have been given for the control of other tractors apply just as well to this machine.

Advice on Tractor Operation.—The operation of a gas tractor will not prove difficult to an engineer familiar with steam tractor operation or to one who is familiar with automobile driving. The main point to remember is that the tractor may be stopped immediately by disengaging the master clutch and applying the brakes. One who has never controlled a heavy machine of this character will first have to become familiar with operation of the steering mechanism. An automobile is provided with a steering gear that is quick to act and one and a half turns of the steering wheelis all that is necessary to turn the wheels from one extreme position to the other. This sensitiveness is necessary on account of the high speed automobiles are capable of. With a tractor conditions are different, the speed is low and considerable weight is supported by the front wheels. This means that a greater number of turns of the hand wheel will be required to steer a tractor than will be needed to direct a motor car. This is necessary because less effort is required from the operator on account of the lower ratio on the worm reduction gearing, and as the tractor is traveling at a comparatively low speed the operator has ample time to turn the hand wheel any number of times that may be desired to insure movement of the front wheels. Most tractors are provided with a crank or small handle extending from the rim of the steering wheel so that this member may be revolved at a higher rate of speed than would be possible if it were grasped around the rim.

The tractor operator should always be careful when operating on highways to avoid hollows or soft ground and mudholes should always be passed by making a

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detour instead of steering the heavy machine recklessly through them. Care should be taken in passing over bridges to make sure that these are of ample strength as many flimsily built wooden structures have failed under the great weight of the tractor for which they were never designed. If the tractor becomes mired and the differential lock is not available pieces of plank, brush, straw or anything that will help traction may be put under the driving wheels. If one wheel is on dry land a tractor will often free itself provided that the differential gear is temporarily put out of commission. This can easily be done on most tractors by bolting a lever carried by the revolving axle shaft to the wheel hub that normally revolves free around it when the differential gear is in operation. This insures that both wheels will turn with the axle and the wheel that is on dry land will provide traction enough to move the machine under these conditions. If the differential gear were in operation the traction member that was in the mudhole and which had the least adhesion with the ground would just spin around, whereas the other member would remain stationary.

On two and three speed tractors the operator should always use that ratio best suited for the work the tractor is doing. In getting from place to place over the roads and for hauling light loads the highest speed of a three speed tractor, which is about six miles an hour, can be used. For hauling heavier loads over the highways the medium speed, which is about three and one-half or four miles per hour, will give the best results. For drawbar work where considerable power is needed the lowest gear ratio, which is seldom over two miles per hour, should be used The tractor should not be operated on the low gear except when conditions demand

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it and if the load is light it is preferable to run on one of the higher gears and throttle the engine down than it is to run on a low gear ratio and run the engine at full speed.

When operating a tractor over hard roads, especially those of the macadamized variety, the operator owes it to the public to remove the grouters, traction points or mud lugs from the rear wheels and run on the smooth steel tire. The use of grouters cuts up a road too much, whereas running with steel tires will offer enough adhesion to secure traction on a hard road and at the same time the road is benefited by the rolling action of the large wheels, rather than being cut up as is the case when the projections ordinarily fitted to increase traction in the field are fitted.

Housing the Tractor.—The average farmer is apt to be negligent in providing suitable quarters in which the various farm machines may be stored. It is a common sight to travelers on trains leaving the East for the Middle West to find costly agricultural machinery out in the open fields alongside of the tracks. If this was confined to but one section of the country it would be reasonable to assume that the failing was not a common one, but the observant traveler, especially if he has economical instincts and is familiar with machinery, will note practically the same condition existing in all States through which he passes. In one field a mowing machine will be seen half mired in a swamp with its vital parts rusting away. In another case it may be only a plough or hay rake or a toothed harrow, but nevertheless, these less expensive machines are wholly without protection and are covered with rust. This sort of treatment means that machines which should have a normal working life of from five to ten years,

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depreciate so rapidly that a perpetual mortgage must be kept on the farm in an endeavor to supply the new machines which are needed very often.

Exposure to the elements is not good for any form of machinery composed of wood and metal. The wood will rot while the metal portions oxidize away and all bearing points and moving parts become so clogged with rust that when the machine is put in service again considerable time is needed to place in a condition where it will be able to do any kind of work. In several cases the writer has observed traction engines hauled up alongside of some decrepit shed or out-house and covered with a tattered old piece of canvas or banked half way up in a snow drift. Of course, it is generally known that the running gear portions of a traction engine are not very sensitive but this does not mean that a tractor should not be given that protection from the elements that is so necessary to secure maximum service and minimum depreciation.

Even the cheapest tractors represent an investment of $1,000 or more and it is not reasonable of the farmer to expect good service from a machine which he leaves exposed to all conditions of wind and weather. An old awning or tent cover or a lot of old bagging is not sufficient protection for a piece of machinery that is as costly as a tractor. Even the poorest farmer will take the proper steps to protect his live stock and in many cases these are housed in more pretentious quarters than he and his family share. It is not necessary that the tractor house should be an expensively constructed or ornate structure but it is imperative that it be substantial and weather proof. Very satisfactory houses may be erected for a few hundred dollars that will insure adequate protection to the tractor.

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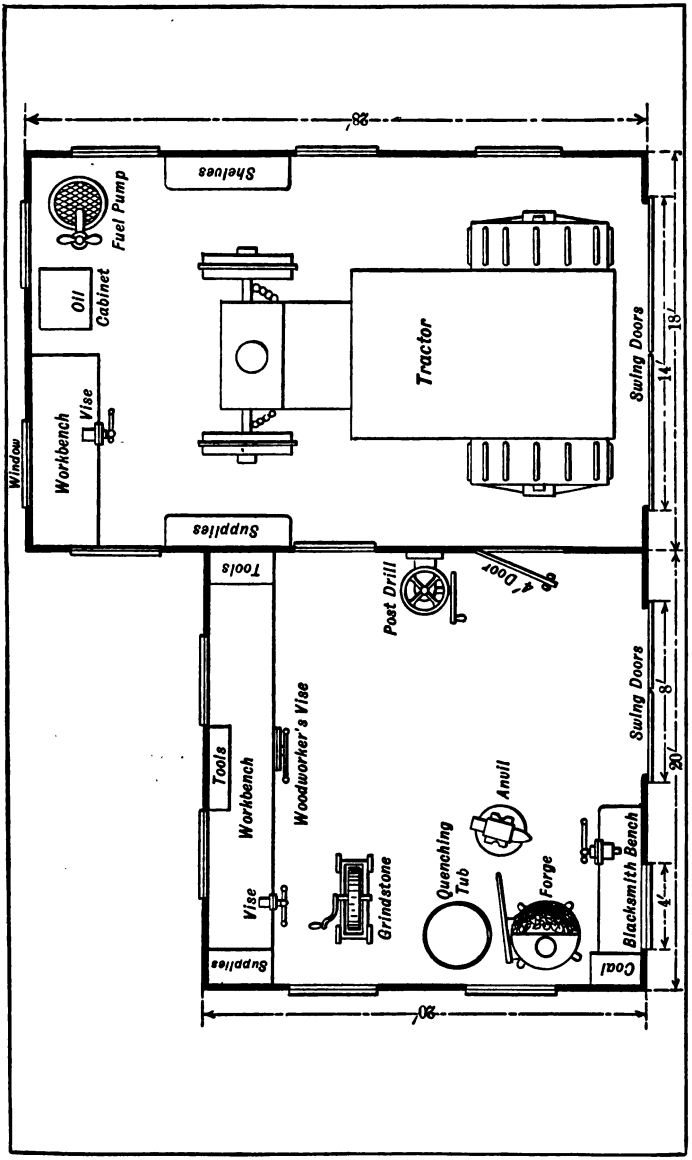

FIG. 149.—Plan View of Combined Tractor House and Farm Machine Repair Shop.

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The farmer about to build a house for his tractor must choose between several different types of construction and in addition to local conditions he must be governed in this selection by proper consideration of cost, safety, durability and fire protection. The tractor house may be of simple frame construction, consisting of ordinary odds and ends of lumber and old planks from some demolished barn or shed as the cheapest example to the more expensive but substantial houses made of new lumber. The shed may be an all steel structure with studding composed of various light structural iron shapes, such as angles, tees, or channels covered with corrugated sheet iron. Of late there is considerable attention being paid to concrete construction and if the farmer has a gravel bank on his land this will make the most satisfactory form of building.

In considering the cheaper types of frame construction for tractor houses, these may be neglected as unsuitable for permanent installation because of lack of durability and an undesirable fire risk which should be given careful consideration if one intends to use the power plant of the tractor as stationary engine during the time that the tractor is not in use in the field. A steel construction, while very efficient and satisfactory, is usually so great in first cost that this will generally prohibit its use for the ordinary tractor house. Reinforced concrete, through the reduction in price of first-class Portland cement and the development of very satisfactory and economical mixtures, has been receiving considerable attention because a very substantial building may be erected at low cost and in a comparatively short space of time.

A building of this nature is free from vibration, does not require repairs or renewal, and offers the maximum

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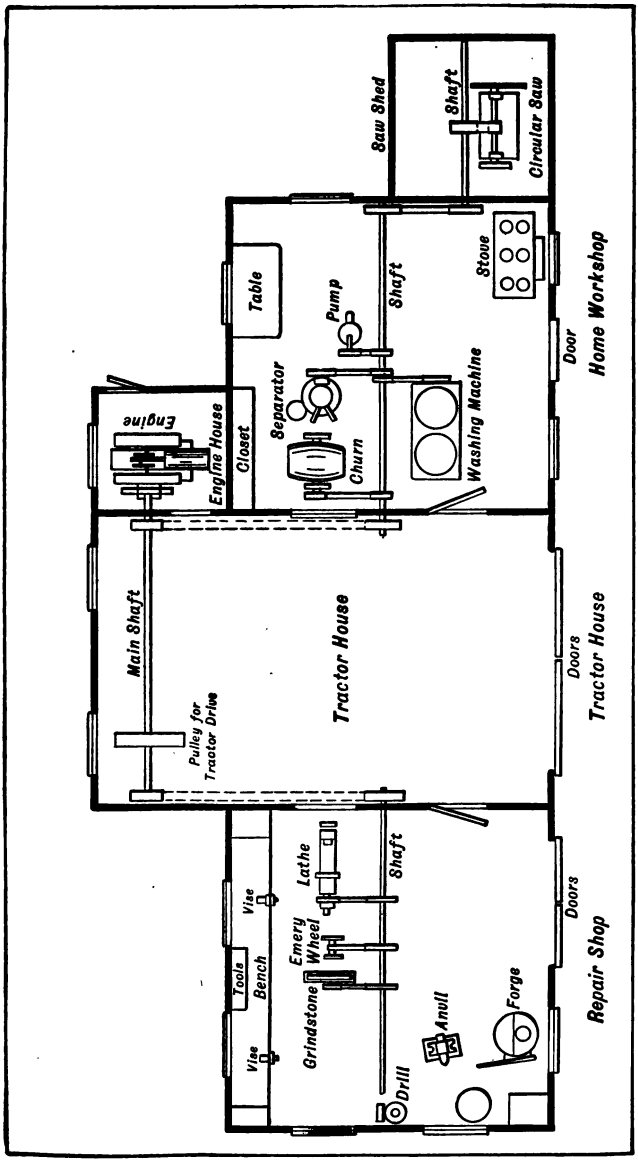

FIG. 150.—Plan View Outlining Suggested General Arrangement of Tractor House With Repair Shop and Workroom.

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fire protection. The exact cost of a building in any case is governed by local conditions. In considering wood construction one should remember that skilled laborers are required to do a really satisfactory job, though very substantial structures have been erected by the farmer and his help without the assistance of a highly paid carpenter. In making a building of concrete one must consider the price of cement, the cost of obtaining suitable sand, broken stone or gravel, the price of lumber for forms and the wages of laborers. As concrete is largely laid by the cheapest kind of labor the high rates necessary to pay for the skilled laborers needed with wood or steel construction can be eliminated.

In designing the tractor house, assuming that one has to be built specially for it, one should make provision to build a structure enough larger than absolutely needed to shelter the tractor so a small work bench may be provided and also ample storage space for the various supplies and spare parts needed to insure continual operation of any piece of machinery. If buildings are already available one should be careful to select a structure which has no cellar because the average floor of a barn or stable is not strong enough to support the great weight of a traction engine which ranges from four tons for a 12 horse-power type to fifteen tons for the 45 and 60 horse-power forms. Care should always be taken when a building with a basement is used that the floor is well shored up by additional posts and strengthened by additional heavy planking to bear the excess strain for which it was not originally calculated.

The size of the building depends largely upon the size of the tractor that is to be housed. A traction engine will vary in width from 7 feet 6 inches to 10 feet, and as it is desirable to have space on all sides,

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it will be well to make the shed in which the tractor is to be housed at least 18 or 20 feet in width. The extreme length of a tractor will vary from 15 feet to 20 feet and here again we should provide plenty of room so that a building 30 feet long will give ample space for housing the largest tractor. The average tractor will be about 10 feet high, therefore the buildings provided for its use should have doors 11 feet in height and about 12 feet in width.

Combined Tractor House and Farm Workshop.—There is another point in which the average farmer is somewhat lax and that is providing himself with a shop of adequate size and with suitable equipment to make ordinary repairs on the various farm appliances. The farm that is up-to-date enough to own a gas tractor should be sufficiently progressive to provide a well-equipped shop where not only the tractor can be repaired but the other farm tools receive attention when needed. A very satisfactory method of doing this is to make a combined tractor house and farm workshop, as outlined at Fig. 149. While one is putting up the garage for the tractor, it does not prove much more expensive to enlarge the structure somewhat and have a separate room in which the various tools needed to do wood work and metal work, such as smithing, can be housed. It is not expected of the average farmer that he qualifies as a blacksmith or machinist, but at the same time there are many little tasks that he can do just as well as the blacksmith or wagon builder that will not only save money by providing work for a period of leisure when conditions do not permit outside work to be carried on but that may also save valuable time during the rush period of ploughing, seeding, or harvesting by saving a trip to town.

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A shop may be equipped with all necessary wood and metal working tools to make ordinary repairs for considerably less than $100. This includes a complete set of carpenter's tools, a forge and blacksmith's outfit, and the various small tools necessary to properly care for the tractor engine. The plan at Fig. 149 shows a tentative layout that may be followed to advantage. In this, the workshop is provided with a long bench at the back end, a portion of which is reserved for wood

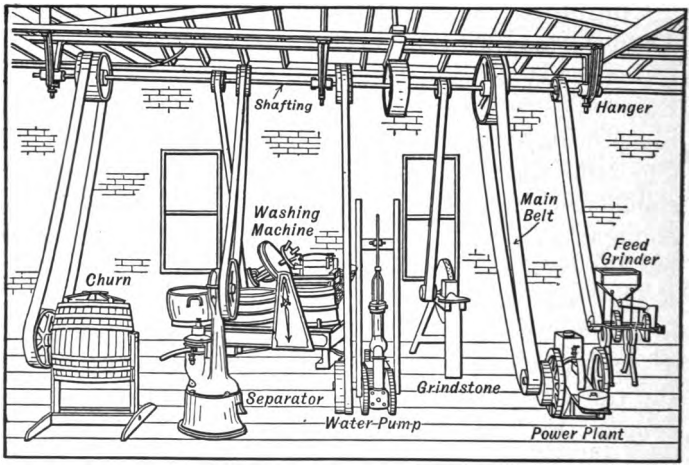

FIG. 150A.—Interior View of Household Workroom in Which Shafting May be Run From Tractor Housed Alongside.

work, while the remainder is convenient to the forge and anvil. An 8-foot door is provided so any farm wagon or other appliance may be run into the building when it needs repairing and be worked on in comfort. While general dimensions are given these and the arrangement of tools may be varied to suit individual requirements.

A more complete combined tractor house and workshop is outlined in plan at Fig. 150. In this provision

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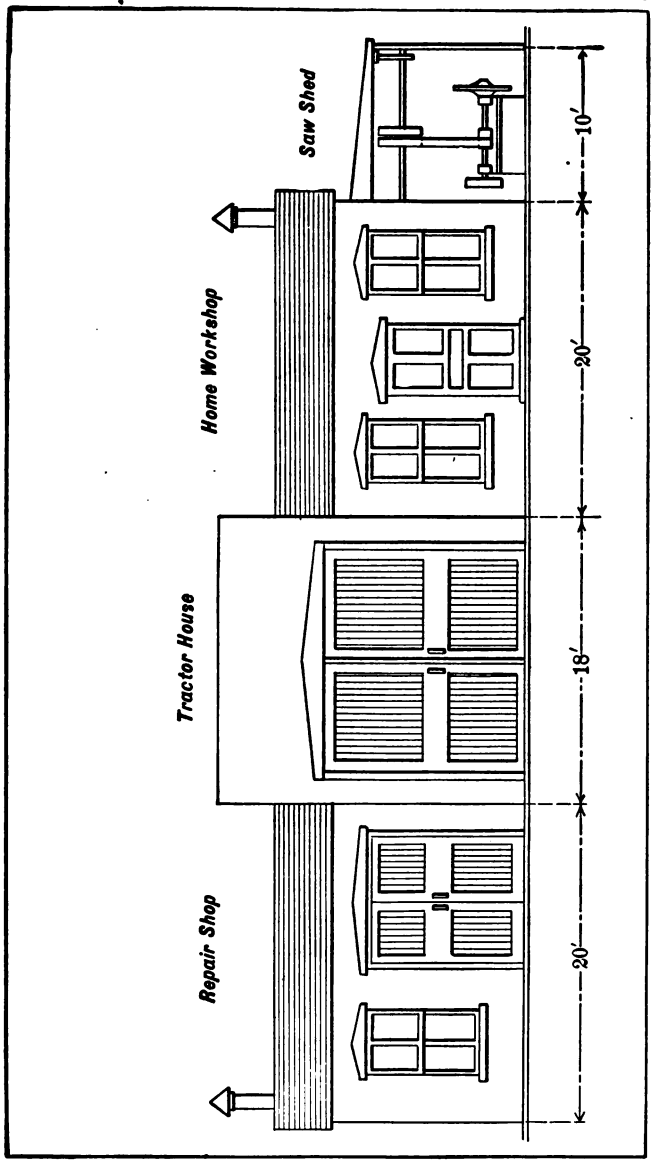

FIG. 151.—Front Elevation of Tractor House With Repair Shop, Workroom and Circular Saw Shed.

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is made so the tractor may supply power to either of the workshops, one of which is disposed at each side of the tractor house. The equipment of the repair shop has been increased by the addition of a lathe and emery wheel which can be used to advantage on any farm where the owner or employees have some degree of mechanical skill. In addition to the repair shop, which is placed at the right of the tractor house, there is a home workshop in which various machines belonging to the dairy or laundry are installed and provided with belts so that they may be run by power. A line of shaft passes through the center of each workshop and is belted to a short line of shaft in the tractor house. This is adapted to be driven either by a gas engine of comparatively low power which is installed in a small power house added on to the tractor shed, or it may be operated by belt direct from the tractor.

When the traction engine is at work in the field, the small gas engine will supply power enough to turn the shafting and run any one or two of the machines in either shop, though when the tractor is used for power there is such a margin that all the machinery can be operated simultaneously. There would seldom be a time when all of the machinery would be working and the tractor be out in the field at the same time, so the small engine which is of 4 or 5 horse-power will prove adequate for the ordinary everyday tasks. It will be noticed that the line shaft from the home workshop projects through the wall and is belted to a circular saw which is housed in a shed or lean-to which forms an extension of the home workshop. It is preferable to house the saw in this manner instead of in a walled room because it is easier to handle the logs to be sawed and the cut pieces with the saw practically out in the

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open. At the same time some degree of protection is offered by the roof of the shed and when enough wood has been sawed for a period the belt may be removed from the pulleys and the saw from the arbor and both stored away while the saw frame may be covered with a piece of canvas which will afford sufficient protection.

The view at Fig. 150-A shows the interior of a home workshop in which the power plant is housed in the same building as the machinery it operates. This shows the various machines which can be conveniently operated by power and which save time and labor. Obviously, the shaft could be extended through into a house alongside in which the tractor could be run when it had done its work in the field and be made to furnish power for this shop as well as for the other machinery in the repair shop. By using a tractor engine in this manner through the winter months, it is kept properly limbered up and the machine is always ready for use. If the tractor house is unheated an anti-freezing compound may be used in the radiator or cooling system and no damage can result when the temperature is low.

Housing a tractor in this manner insures that it will receive attention during the idle period as it is an inducement to the workmen to make repairs on a machine that is comfortably housed, whereas they would not desire to work around the same machine if it was in the open and exposed to the elements. The view at Fig. 151 shows the appearance of the shop and tractor house outlined at Fig. 150 when viewed from the front. Combination structures of this character may be built by using concrete blocks or reinforced concrete construction for the tractor house while the adjacent shops may be made more lightly from lumber. This is a good combination, as the tractor house is fireproof and

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wooden structures are adequate to house the various household and repair equipment. A hard dirt floor should be provided in the tractor house, this being sloped either toward the center of the floor or to one end where a drain should be placed that will allow any drippings from the tractor to run out.

The tractor house should be well ventilated in order that no gasoline fumes can accumulate and some means should be provided for disposing of the exhaust of the engine so this will be directed to the outer air, instead of being confined in the tractor house. A hood of sheet metal may be placed directly over the exhaust pipes so the exhaust gases will be directed through the roof or a pipe with a quickly detachable connection that will fasten to the exhaust pipe of the engine may lead the gases to a muffler if it is desirable to reduce the sound of the escaping exhaust. A good muffler for this purpose is easily and cheaply made by filling a hogshead with large stones leaving it open at the top and connecting the exhaust pipe to the bottom. The stones will break up the exhaust gases and muffle the sound so that it will not be objectionable. A cowl should be placed over the hogshead so that rain cannot get in but at the same time sufficient opening should be left around the edges so the gases will escape freely to the atmosphere.

Fuel Storage Methods.—An important problem confronting the man who takes care of either his own tractor or automobile and stores it in a special motor house in close proximity to a residence or other building is that of gasoline storage. There are three methods available. A very dangerous one commonly practiced is to keep this highly inflammable liquid in five or ten gallon cans in the tractor house, the second is to have

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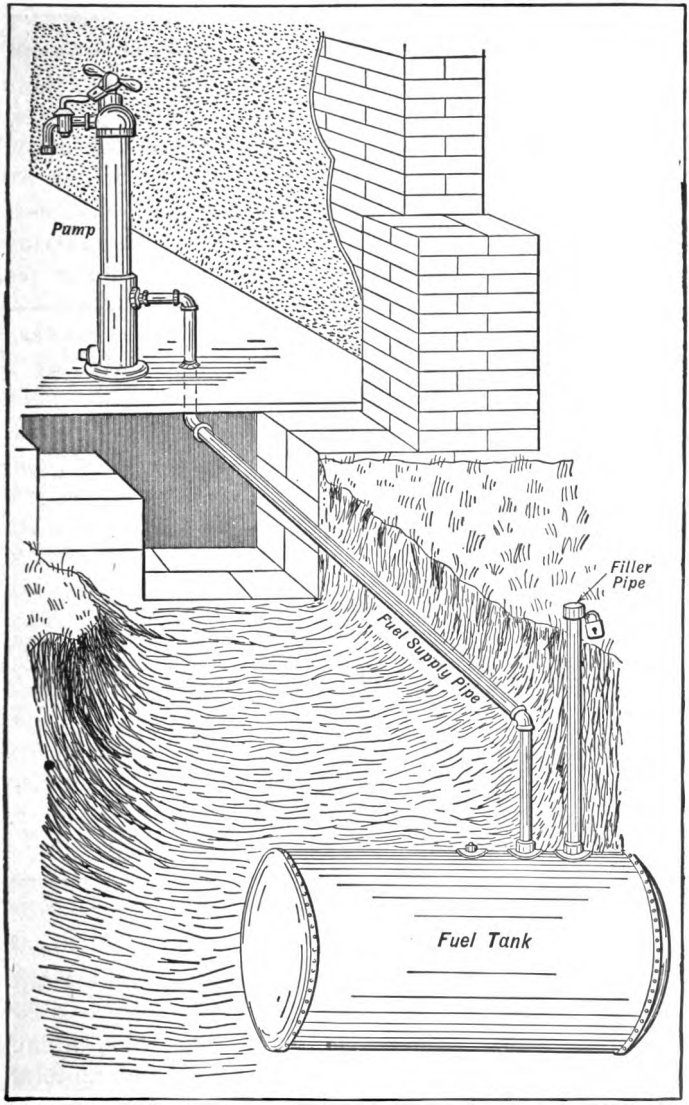

FIG. 152.—Arrangement of Parts of Approved and Convenient Fuel Storage System for Tractor House.

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a separate structure especially for gasoline storage, while the third is to install an underground tank, there being several excellent types in the market. The last mentioned is to be preferred from the viewpoint of safety, though the average farmer does not take kindly to this because of what is considered the high first cost of even a simple storage outfit of first-class construction. Storing the gasoline in cans is not desirable for

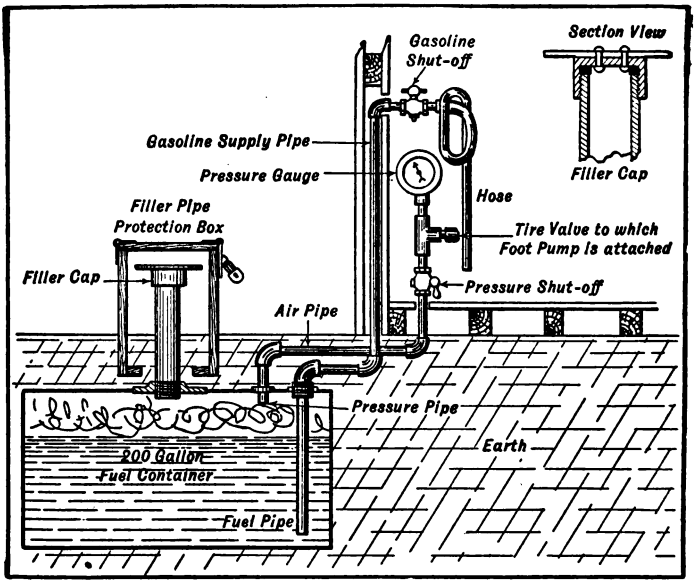

FIG. 152A.—A Simple Home-made Underground Gasoline Storage System That is Economical and Easy to Make.

several reasons, chief among which is that storing the fuel in this manner makes for considerable loss by evaporation and by leakage or spilling when filling tanks directly from the container. An underground storage outfit of excellent construction and of simple

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design, which should not prove costly, is shown at Fig. 152. In this the fuel is stored in a large tank buried underground outside of the garage or tractor house, while a hand operated pump of the suction type is inside the shelter and protected from the elements. At Fig. 152-A an underground gasoline storage outfit which can be installed at low cost and made by any one of average mechanical intelligence is outlined.

This consists of an air-tight copper or steel tank, well coated with asphaltum paint, preferably, though a galvanized iron container can be used if desired. The construction should be such that the tank will resist air pressures up to 40 or 50 pounds per square inch. Three spuds are placed in the top of the tank, one to take two-inch standard iron pipe, the others to fit one-half and one-eighth gas pipe respectively. A two-inch pipe cap, to which a piece of one-half by one-quarter inch bar stock is attached by machine screws or rivets, is used for a filler cap at the end of the piece of large pipe. This is cut of sufficient length so that the tank can be buried underground below frost line and still leave four or five inches of pipe projecting above the surface after the hole in which the tank was placed is filled.

A special reducing fitting is made to fit the spud, tapped one-half inch pipe size, this to take a piece of one-quarter inch pipe, which extends to about an inch from the bottom of the tank and projects above the surface of the reducing bushing. A standard ell is then screwed in place and the piping continued as shown in sketch. A piece of one-eighth gas pipe runs from the other spud to a T piece from which a branch extends to an air pressure gauge, and in which is placed a short piece of pipe having a ball check fitting

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or the usual universal tire valve. At the end of the one-quarter inch pipe, which runs up inside the motor house, is placed a ground shut-off fitting, to which a piece of rubber hose ten or twelve feet long is attached. It is advisable to make both the one-quarter and one-eighth inch pipe lines of brass, and to solder all joints

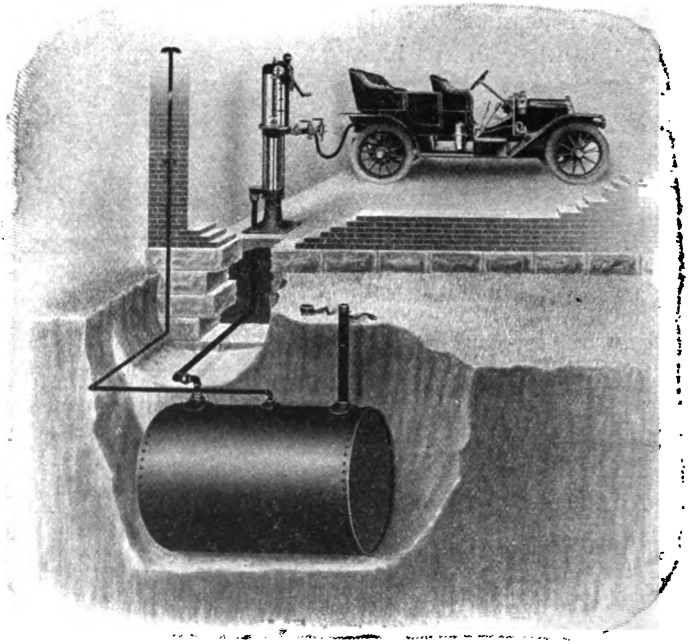

FIG. 152B.—Bowser Underground Fuel Storage System for Automobiles or Tractors.

as they are made, to insure absolute tightness at all points and eliminate all possibilities of leakage. The small petcock placed below the valve fitting is to be closed except when it is desired to take a gauge

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reading or when an ordinary foot pump is coupled to the valve to compress more air in the tank. This fitting when closed prevents leakage of air through the check valve, which might result if this was depended upon to retain the compressed air in the container.

The handle on the filler cap is convenient in filling the container as it provides leverage and makes easy the removal of the cap from the pipe. This may be protected by a strong wooden box, with a hinged cover, provided with a hasp and padlock to prevent tampering with the contents. The tank may be of any desired capacity, but one holding about 200 gallons will answer the requirements of the average tractor operator. The filler cap should seat against a piece of soft packing to insure an air tight joint on the filling pipe. The tank should be placed as close to the wall of the tractor house as possible to simplify piping. After the container is filled with fuel to about seven-eighths its capacity to leave an air space, an ordinary foot pump is coupled to the air valve in the pressure pipe and air supplied to the tank until the gauge indicates a pressure of 15 or 20 pounds a square inch on top of the liquid. In filling a tractor tank, it is merely necessary to place the end of the rubber hose in the tank opening and turn on the supply, and after sufficient fuel is drawn the shut-off fitting may be closed. As the supply of gasoline becomes less, more air should be forced into the main container. The installation is not costly, and the material needed, with the possible exception of the tank, can be obtained in almost any town or village, and its simplicity and utility will be appreciated by the practical farmer. All fittings are indicated in the drawing and there should be no difficulty in assembling the outfit.

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Tools and Equipment for Care of Tractor.—The farmer who intends to take care of this own tractor or one who has several of these machines will find need for a number of tools of a slightly different character from those generally used in repairing farm implements. A set of small tools most likely to be used should be carried on every tractor, as often repairs of a minor nature must be made in the field. In the illustration (Fig. 153) a comprehensive outfit of small tools and devices that will be found especially valuable in making repairs for the tractor engines or transmission system are outlined. The tool roll contains an assortment of tools that are more generally used and is a modified form of the tool kit generally supplied for automobile repairing. The only difference between the tools is that these are larger and more substantial in order to handle the more rugged parts of the tractor mechanism. The tool roll shown contains all necessary wrenches, pliers, screw drivers, punches, drift pins, chisels and files, as well as miscellaneous supplies necessary to make ordinary repairs.

In addition to the tools outlined a small bench vise that can be attached to the step or tool box cover of the tractor will be found of considerable value. The large file assortment may be kept at the workshop for use in making more extended repairs. This is true also of the carbon scrapers, the valve spring lifter and the hand drill. The hacksaw, hand vise and tinner's snips occupy but little room and can be conveniently stored away in the tractor tool box. The blow torch will be found very desirable in providing a source of heat for the soldering iron and for loosening rusted on nuts and for many other purposes that will suggest themselves. Among the general supplies that should be included

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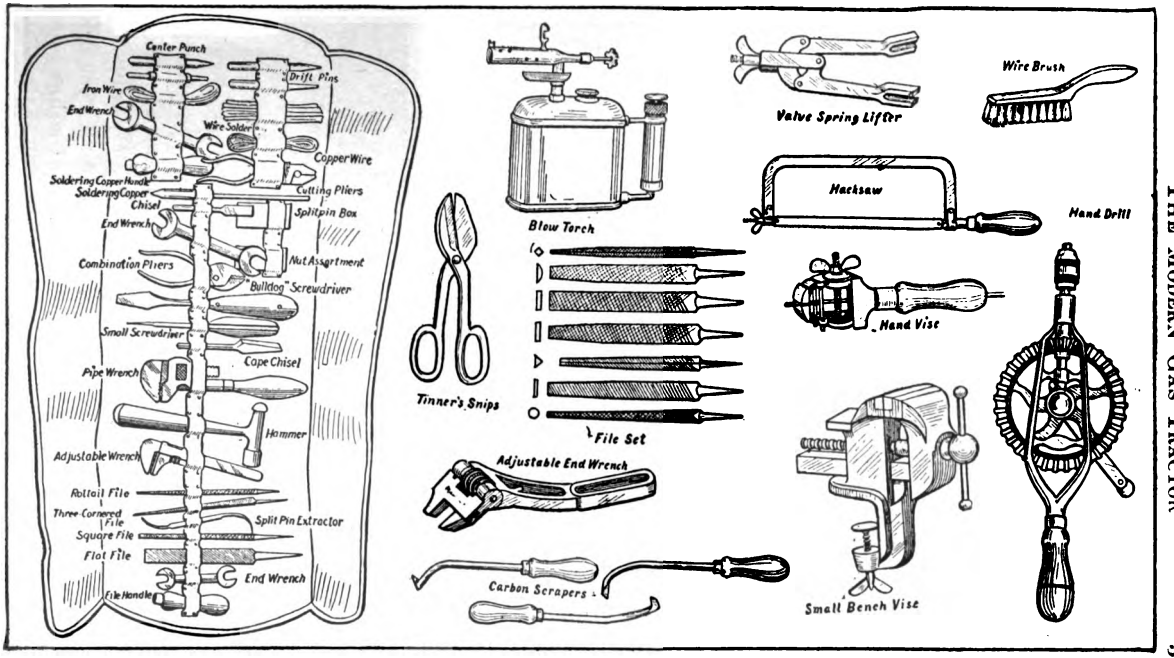

FIG. 153.—Tools That Will be Found Useful in Working Around Tractor Mechanism.

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in the equipment are spare spark plugs for the motor, a few feet of primary and secondary electric wire, material to make the various gaskets and packings used on the engine, a quantity of cotton waste or old rags, an emergency supply of cylinder oil for the lubricator and hard grease for the grease cups. The other supplies or spare parts needed will vary with the type of tractor and the distance it is to be operated from a base of supply.

The writer has made mention of the fact that an outfit of blacksmith's tools may be obtained at relatively small cost. As these enter largely into the care of the tractor and auxiliary appliances it may be pertinent to enumerate the contents of a complete blacksmith's outfit which is illustrated at Fig. 154 and which can be purchased for $35 to $40. This consists of a 60-pound anvil with tool steel face; a 35-pound wrought iron blacksmith's vise; a portable lever forge, provided with a compact blower for supplying draft, and a two-speed self-feed post drill which takes up to half inch round shank drills and will drill to the center of a twelve-inch circle. The miscellaneous small tools include a die stock and dies, a set of standard taps, one hot cutter, one cold cutter, a hardie, a pair of flat-lip tongs, one pair of pincers, one farrier's knife, seven drill bits, one farrier's hammer, one hand hammer and a monkey wrench.

A few other tools, such as a medium weight sledge hammer, a more complete assortment of tongs, two or three rasps, a set of heavy files, and an assortment of standard bolts and nuts, as well as blanks which may be threaded as required, will be found valuable. The stock needed may be purchased at small cost and will include various sizes of round, flat and square bar

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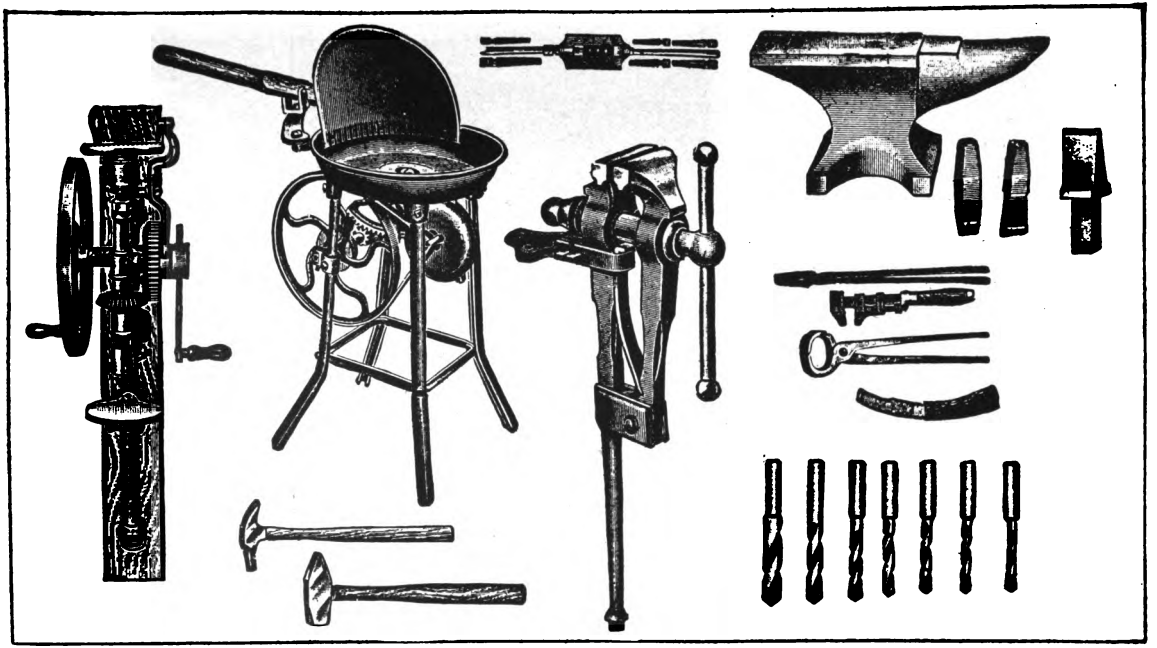

FIG. 154.—Blacksmith Shop Equipment That Will be Found Useful in General Farm Work as Well as Tractor Repairing.

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iron and steel. All the odds and ends of iron or steel, as well as cast-off bolts, tie-bars, turn buckles, iron hoops, etc., that ordinarily go to waste, may be picked up and put in a stock box with the assurance that they will be found useful at some future date.

No workshop will be complete without a set of wood working tools and very fortunately a very practical outfit can be purchased at comparatively small cost.

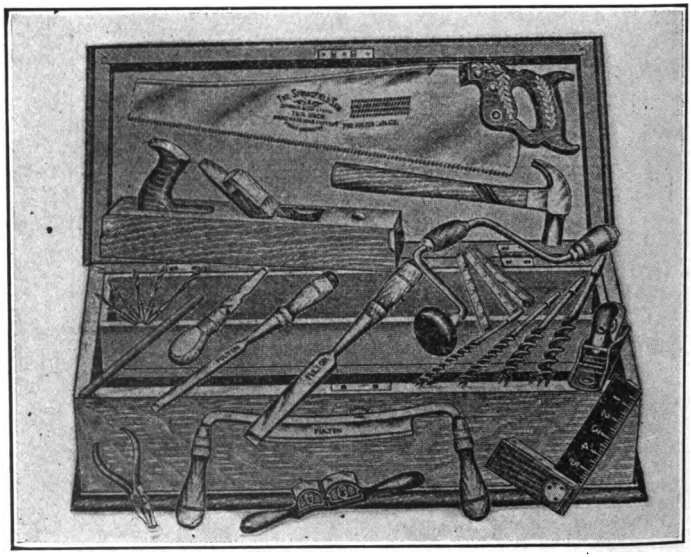

FIG. 155.—Complete Set of Carpenter's Tools a Useful Addition to Farm Repair Shop Equipment.

Wood working tools are not only necessary in the farm workshop but are of obvious utility in making repairs incidental to the upkeep of buildings, fences, and the erection of new structures. A very convenient outfit for use around the farm or shop is shown at Fig. 155

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and can be purchased for $12 to $15. It consists of the following tools: One 22″ hand saw, one 6″ try square, one 2′ rule, one pair 5½″ combination pliers, one 10″ bit brace, four auger bits, one each size ⅜″, ½″ ¾″, and 1″; five gimlet bits, one steel hammer, one 8″ draw knife, one double cutter spoke shave, one 5″ steel blade screw driver, two socket chisels, one jack plane, one 5½″ iron block plane and a carpenter's pencil. A plumb bob and chalk line, nail set, level and a large steel square can be purchased to complete this outfit at slight added expense. The hardware necessary, such as nails, screws, staples, locks, hinges, etc., can be purchased as required and soon enough of these supplies are left over when purchases are made from time to time so a very useful stock of miscellaneous small hardware accumulates without its cost being so apparent as would be the case if everything that was thought desirable was purchased outright.

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CHAPTER X.

TRACTION ENGINE TROUBLES AND ELIMINATION.

Location of Defects and Remedies—Loss of Power—Poor Compression—Carbon Deposits—Valve Grinding—Timing Valves—Care of Piston and Rings—Noisy Operation—Adjusting Bearings—Mixture Troubles—Ignition System Derangements—Cooling and Lubrication Group Faults—Running Gear Derangements—Tractor Hitches—Utility and Uses of Modern Gas Tractor—Homemade Gas Tractors—Auto Tractor Attachment—Future Possibilities.

Location of Defects, and Remedies.—The derangements that interfere with satisfactory tractor operation may exist in either the tractor power plant which includes the engine and auxiliary groups or in the running gear assembly in which the clutches, transmission, driving and differential gearing, as well as frame, wheels and axles are included. The troubles with the power plant are the most difficult to detect because there are a number of different conditions that may produce the same symptoms. Running gear faults, as a rule, are easily located because they are usually due to some loose or damaged part that may be easily noticed on inspection.

One who is familiar with mechanical construction and practical operation of tractors will have no difficulty in tracing common motor troubles to their source, but while the expert readily recognizes the symptoms which show derangement of the various power plant components

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the average farmer or tractor operator is apt to waste a lot of time and energy in trying to locate trouble unless he does so by a systematic search for defects. The internal combustion motor or gas engine, which is utilized as a power plant on practically all gas tractors and which is clearly shown in Figs. 156 and 157, is composed of a number of distinct groups which have been previously described in detail. These various

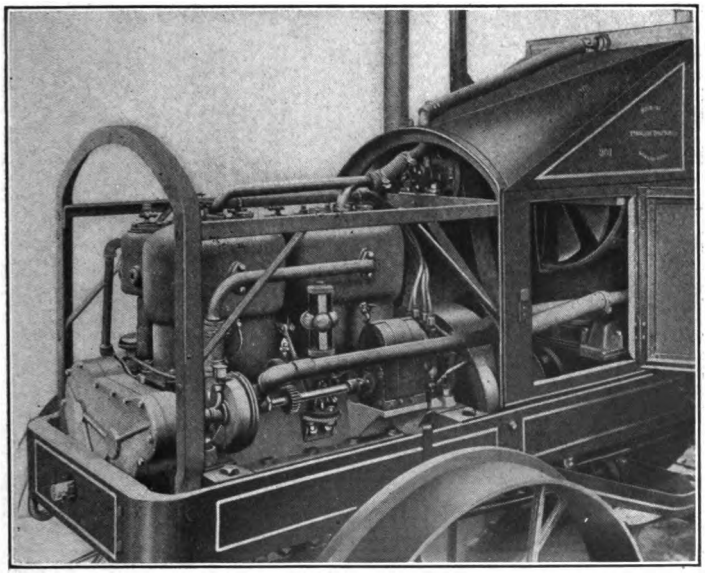

FIG. 156.—Power Plant of Phoenix Tractor Showing Water Pump, Governor Assembly and Ignition Magneto.

auxiliary devices are closely related to each other and defective operation of any one of these may seriously affect the power plant or stop it altogether.

The careful tractor driver will always inspect the motor and other points of the mechanism liable to de-

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rangement before starting on a run of any consequence, and if inspection is carried out in a systematic manner and any loose nuts, wires or other fastenings are given attention it is seldom that irregular operation will be due to any broken parts. The natural wear and the depreciation which it causes occur slowly and when parts begin to deteriorate sufficient warning is always given

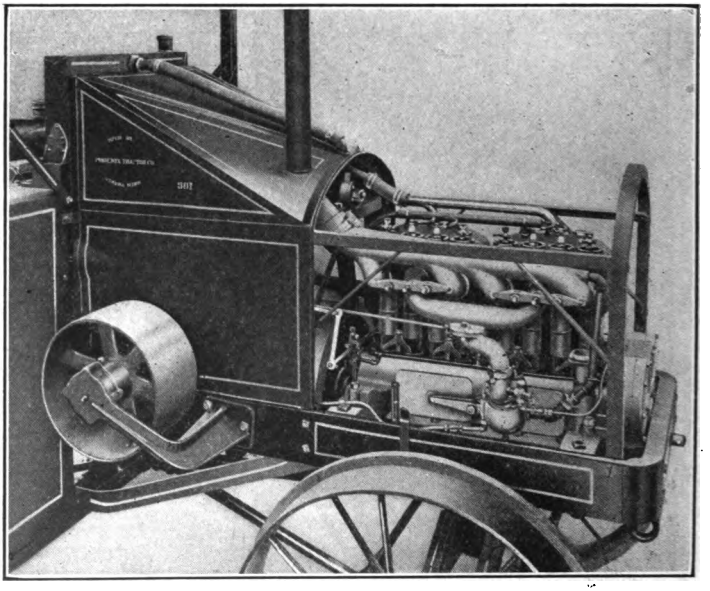

FIG. 157.—Valve Side of Phoenix Four Cylinder Tractor Motor Showing Crankcase Inspection Plates, Inlet and Exhaust Manifolds and Carburetor.

so that repairs may be made promptly, and thus serious derangement is prevented.

The main troubles with the power plant are loss of power, irregular action, overheating, and noisy operation. The first usually denotes some fault in the piston

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rings or valves of the engine and is due primarily to poor compression. Irregular operation, which is the condition that exists when cylinders do not fire regularly, is nearly always the result of defects in the gas supply system or the ignition appliances. Overheating invariably denotes inadequate lubrication or failure of the cooling system. Noisy operation can always be accepted as a condition due to mechanical wear.

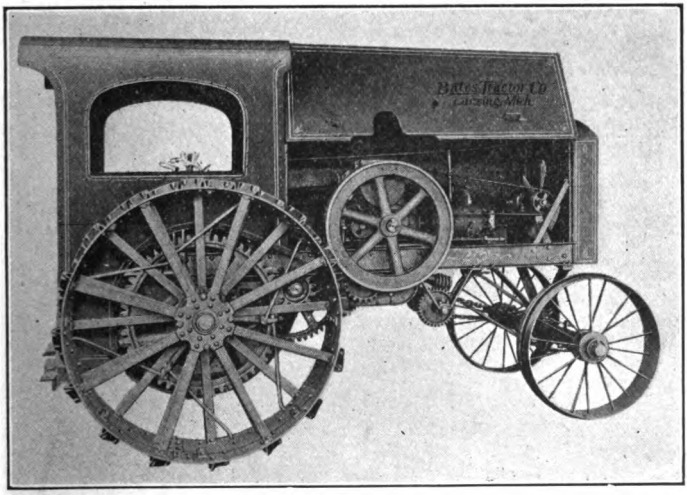

FIG. 158.—Side View of Bates Gas Tractor Showing Accessibility of Power Plant When Automobile Type Motor Hood is Raised.

Loss of Power.—While loss of power is usually a condition that can be ascribed to poor compression it will result indirectly if any of the other faults are evident. Obviously, if an engine is missing explosions and is not firing regularly its power will be reduced materially and thus the condition of "skipping" or "missing fire" as it is called will produce loss of power indirectly. If

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the engine is overheated so the various parts are running with considerable friction there will be a loss of power because of the increased internal load in the motor itself. Overheating may be directly caused by failure of the oil supply in which case the consequences are apt to be serious unless the motor is stopped as soon as this defect is apparent. Troubles with the cooling system are easily determined by the steam which issues from the radiator or cooling tank.

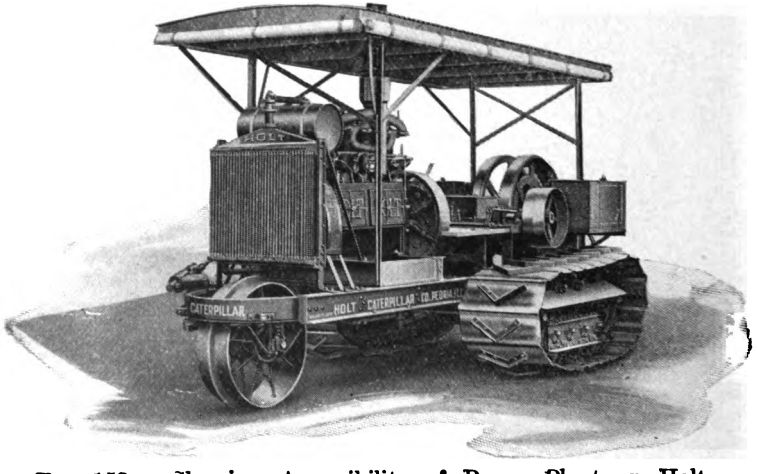

FIG. 158A.—Showing Accessibility of Power Plant on Holt Caterpillar Tractor.

Tractor power plants are generally housed in an accessible manner, if they are under a hood or bonnet, as outlined at Fig. 158, or may be easily reached as ordinarily mounted in unprotected positions on the tractor frame. The power plant shown at Fig. 159 has been photographed in position on the frame with other parts removed in order to show clearly the method of placing a typical tractor motor and the auxiliary devices

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upon which its operation depends. The location and method of drive of the magneto which forms the ignition system and that of the mechanical oiler, which supplies the engine with lubricant, is clearly outlined. The valve springs are placed at the top of the cylinders and are easily reached when it is desired to relieve the valves of their tension so that these members may be ground. The centrifugal governor and the linkage by which it controls the throttle valve are also clearly outlined. Attention is called to the inspection plates on top of the engine base through which the interior portions of the crank case may be easily inspected. These plates are readily detachable by loosening a bolt that holds them in place by a clamp bar, the ends of which bear on the center portion of two plates.

If it is desired to remove the cylinders, the first step is to take off the exhaust and intake manifolds, then the cylinder pair may be pulled off of the engine base by removing the nuts that hold it in place. The valves may be ground without removing the cylinders, and in fact all working parts of this motor may be reached without taking the lower portions of the crank case or engine bed from its position on the tractor frame. If adjustments are necessary to the bearings of the crank shaft, the top half of the diagonally divided crank case may be removed without difficulty by loosening a few oil pipes and the connecting link between the governor and the throttle chamber. When this top plate is removed the entire interior of the crank case, including the cam shaft, is open for inspection.

The point of accessibility is one that is given special prominence in the design of tractor power plants, much more so than is the case in the small gas engines used for automobile propulsion. This is on account of the

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large size of the tractor engine parts and the difficulty which obtains in handling them without proper facilities. As an example of a construction that permits maximum accessibility, the illustration at Fig. 160 is presented. This shows a workman removing the piston from the interior of a gas tractor cylinder without removing the latter from the engine base or taking the engine bed from its position on the tractor frame.

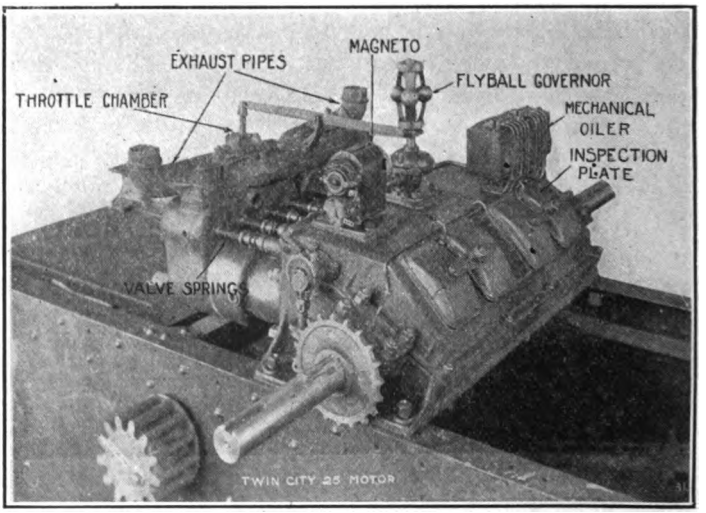

FIG. 159.—Power Plant of "Twin City 25" Gas Tractor Showing Accessibility of Auxiliary Parts. Valves and Valve Springs and Crankcase Interior Inspection Plates.

Most traction engine designers endeavor to have all parts accessible as this is one of the first things that the experienced tractioneer looks for when purchasing a new machine.

A breakdown in the field is not always serious if the parts can be readily reached, but at the other hand, it

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may mean the expenditure of considerable time and money if the entire engine has to be dismantled every time the interior mechanism is out of order. There are some automobile engines where it is practically impossible to reach the pistons without taking the cylinders off of the engine bed and where the entire engine must be taken apart to get at the main bearings of the crankshaft or the bushings in the big ends of the connecting

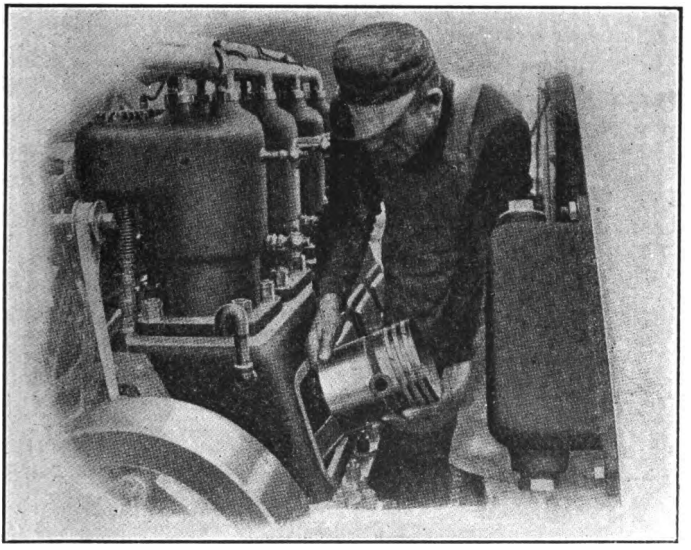

FIG. 160.—Showing How a Piston of Gas Traction "Big Four" Engine May be Removed From Cylinder to Inspect Rings and Remove Carbon Deposits From Piston Top.

rods. This is not tolerated by the expert gas tractor operator, and the factor of accessibility of components alone may make or prevent the sale of a machine.

Poor Compression.—If the engine is losing power and the power loss is not accompanied by skipping,

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overheating, or noisy operation, it is due to poor compression. This results from conditions inside or outside of the cylinders that will allow leakage of gas from the interior. Gas may escape through defective valve operation caused by the valves not seating properly or being out of time. If the valve system is all right the trouble is generally due to faulty piston rings or worn or scored cylinders. The method of testing for poor compression is simple, consisting of cranking the engine without the ignition system being turned on and with compression relief cocks closed. If the engine turns over easily and no appreciable resistance is felt, it is invariably due to a loss of gas from one or more of the cylinders. If it is a multiple cylinder engine the defective member may be easily determined by cranking over the motor with all of the compression cocks, except one, open. Each cylinder is tested in turn and the thing to remember is to keep the compression cock in the cylinder that is to be tested closed, while the others are left open so that the engine can be turned with minimum resistance. The cylinders that have good compression will offer a decided resistance to turning the crankshaft, while those in wh'ch compression is weak will permit one to turn the crank very easily.

If compression is poor the first thing to do is to inspect the external parts which may be easily reached. This means looking for a leak at valve chamber caps, spark plug gasket, or blown packing between cylinder and cylinder head, if that construction is employed. Other causes are broken valve springs, sticking or bent valve stems, valve plunger stuck in guide, loss of clearance between valve stem end and top of valve operating plunger (usually caused by loose adjusting screw which has worked up and kept the valve from seating) or a

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defective priming cock. Some of the defects of the internal parts which may be looked for are a broken valve, a warped valve head, dirt under valve head, which prevents valve from seating, burnt or pitted valve seat or valve head, cracked piston head or cylinder (rarely occurs), broken piston rings, piston ring slots in line, loss of piston ring elasticity or spring, or piston rings gummed in the piston grooves. The piston and cylinder walls may be badly scored by defective lubrication or a deep groove may have been cut in the cylinder by a loose wrist pin which allows the gas to blow by very easily.

Carbon Deposits.—One of the fertile causes of general motor inefficiency and one which often contributes to loss of power, as well as noisy operation, is the deposit of carbon that accumulates in the combustion chamber. These deposits result from burnt cylinder oil and sometimes from excessively rich mixture, and are more apt to exist on motors operating on low grade fuel such as kerosene or distillate, than in gasoline engines where combustion is more perfect. These deposits accumulate on the piston top and in the interior of the combustion head and valve chamber. They interfere with correct valve operation by gumming up the valves and prevent a full charge from reaching the motor, as well as retarding the prompt expulsion of burnt gases by building up around the valves.

The deposits in the cylinder head may cause trouble owing to some projecting particle remaining incandescent from the heat of a previous explosion and firing the fresh charge prematurely. Carbon deposits always produce loss of power, but their presence is usually clearly indicated by a pronounced knocking or pounding noise. The only remedy for this defective condition

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is to remove them from the engine interior. This is done by scraping away the material with small hoe-form steel scrapers that may be inserted through the holes left when the valve chamber caps are removed or by removing the cylinder head if the construction permits. This is one of the marked advantages of the detachable head design. The head may be removed without disturbing the rest of the motor and the deposits of carbonaceous substance may be scraped from both cylinder head and piston. If the deposits are of long standing it wi l be necessary to dismantle the motor in order to reach them and secure their positive removal.

This accumulation may be prevented by careful supervision of the amount of oil supplied the motor, making sure that it is never in excess of the actual requirements, using only the best grades of cylinder oil having a high fire test, and by careful regulation of the mixture to insure that the fuel and air proportions will be those that will burn without leaving a residue.

These deposits may be reduced to some extent by injecting three or four tablespoonfulls of kerosene into the cylinders at the end of a day's run, through the priming cocks. This softens the deposit which has accumulated during the day and when the engine is started up the next morn ng the disso.ved carbon will be ejected through the exhaust as it will be carried out by the burnt gases. The soft deposit is not difficult to cope with, and in fact, various chemical carbon removers are advertised quite extensively which will remove it without making it necessary to take the motor apart, provided the accumulations are not of too long standing. The hard, thoroughly baked on carbon can only be removed by mechanical means.

Valve Grinding.—The most common cause of lost

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compression is leaky valves, and this condition materializes on even the best constructed traction engine. This is one point that requires periodical attention, and as a rule the first thing done, if the engine lacks power, is to grind in the valves to a new seating. The inlet valves do not need grinding as often as the exhausts do, but they are generally refitted at the same time that the exhaust members are ground to a new seat. When a valve needs grinding the defective conditions that make this necessary are apparent at a glance.

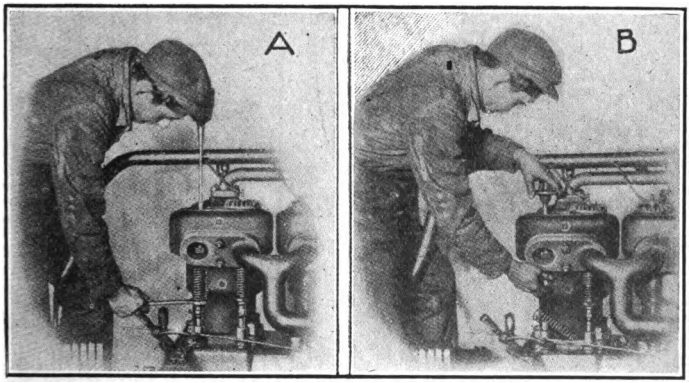

FIG. 161.—How Valve Spring and Valve May be Removed From Gas Tractor Engine Cylinder.

The first step when valves are suspected is to remove them from the cylinder. The method of doing this is clearly outlined at Fig. 161. It is necessary to release the valve spring pressure sufficiently so the key which keeps the collar against the lower end of the valve spring in place may be withdrawn from the valve stem. The method of doing this is shown at A. The first operation is to remove the valve cap, then the manifolds may be taken from the motor. The valve head is then kept

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in place by pressing down on it with a screw driver and the valve spring is raised either by means of a special valve spring lifter or by using an end or S wrench or any other fork form tool that will raise the valve spring without touching the valve stem. After the pin or key is withdrawn from the valve stem, the valve may be easily lifted from the cylinder, as shown at Fig. 161-B.

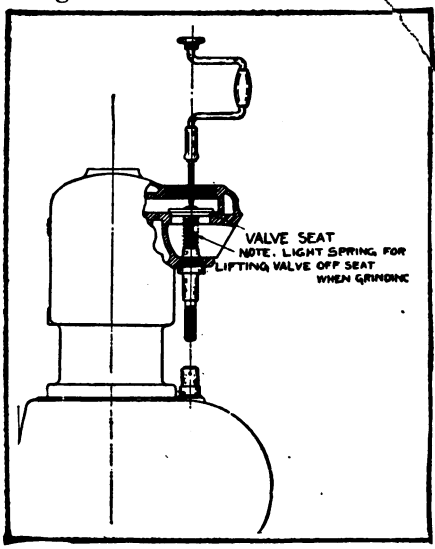

FIG. 162.—Method of Using Bit Brace and Screwdriver Bit in Grinding Valves.

The method of valve grinding is simple and one way of accomplishing this is shown at Fig. 162. Before the valve is replaced in the cylinder the stem is thoroughly cleaned by means of emery cloth and all gummed oil is cleaned out of the valve stem guides. A light spring is placed between the valve head and the end of the valve stem guide in order to raise it from its seat when pressure on the grinding tool is relieved. Special and somewhat costly valve grinding tools have been devised, and while these members are thoroughly practical, a very efficient and satisfactory appliance, which is almost universally used, is the ordinary bit brace. A screwdriver bit is made to turn the valve, provided that the head is properly slotted to receive this form

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of tool. Sometimes the valve head is provided with two holes, and is then turned by a simple forked tool, which may be easily hammered up to shape so it will fit the bit stock.

The faces of the valve and the valve seat are smeared with a mixture of emery and oil made into a thick paste. If the valve surfaces are deeply scored or pitted it will be necessary to start grinding with a medium grade emery. In grinding only sufficient pressure to keep the valve against the seat is used and this is relieved from time to time in order that the valve may be lifted from its seat by the coil spring beneath it. Valves are not ground with a continuous rotary motion. The oscillating motion that would result if the bit stock was turned nearly a complete revolution and then back around again is better, lifting the valve from the seat frequently to prevent the accumulation of little balls of emery which may score the seat quite badly. Too much pressure will also do more harm than good. The valve should be taken from the cylinder and the valve head and seat thoroughly cleaned with gasoline. New abrasive should be used each time the valve is replaced for grinding.

After most of the roughness has been smoothed down and the valve head and seat begin to have an even appearance which is an indication of a smooth surface, the mixture of medium grade emery and oil may be replaced by one of flour emery, crocus, or ground glass, which may be mixed with kerosene, instead of the heavier lubricating oil. These make fine mixtures for polishing valve seat. When the valve has been properly ground it will be smooth and have a bright ring all around its face. The valve seat will also show bright. An important precaution to observe when grinding valves,

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especially on horizontal motors, is that none of the abrasive reaches the interior of the engine cylinder. This is easily done by blocking the port or passage between the valve and combustion chamber with a wad of cloth, to which a string is attached so it may be withdrawn from the cylinder without trouble in case it should become dislodged from its position and fall in.

Timing Valves.—When the grinding process is completed and the valve springs have been replaced, it will be well to see that the valves are timed properly before the manifolds are put back. An important point to observe is that the proper amount of clearance between the end of the valve stem and the plunger is retained. During the process of grinding it may be possible to bed the valves down enough so that the stems will project farther down and bear against the valve plunger before the valve head seats in the valve chamber. After valves are ground it is good practice to go over the engine timing carefully and verify it. The flywheel of most tractor engines of the multiple cylinder form is usually marked with letters which indicate the points where the valves open and close. The crankshaft should be turned by the starting crank, and when the point on the flywheel that indicates valve opening is in line with the trammel or indicator that usually indicates the vertical center line of the engine, there should be no clearance between the valve stem and the plunger that operates it. When the other valve is open in the same cylinder, then there should be an appreciable clearance between the valve plunger and end of valve stem. This is given as 0.007″ for the inlet valves and 0.01″ for the exhaust valves. More clearance is provided between the exhaust valve

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stems and plungers on account of the greater expansion of these members due to heat.

If the engine timing has been disturbed, as is often the case when an engine is dismantled, care should be taken to replace the timing gears just as they were before the engine was taken apart. This is usually indicated by marks made by the manufacturer of the motor. If no marks are noticed, then the tractioneer should be careful to make some for himself in order that he will be sure to replace the timing gears correctly. The best way to do this is to bring one of the pistons, preferably that in the front cylinder, to the top center and to see that both valves in that cylinder are closed. One tooth on the crankshaft gear is then marked with a center punch, or steel letter stamp or even with a cold chisel, if neither of the others is available. The teeth on the larger gear which drives the camshaft on either side of the marked tooth on the crankshaft gear are then marked for future identification in the same manner.

In case the engine timing is lost and the gears or flywheel are not marked, the traction engine operator may approximate the proper timing as follows: The piston in either the front or rear cylinder is brought to the end of its upward stroke and the camshaft is rocked in such a manner that both valves are closed. The timing gears are then meshed and locked into place. The engine crankshaft is then turned about half a revolution and the exhaust valve is watched to see if it rises from its seat. If it rises from its seat when the piston is about three-quarters of the way down on its stroke, the engine may be considered timed approximately correct and if nothing else has been disturbed, such as the cams on the shaft, etc., the rest of the

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cylinders will undoubtedly be timed correctly enough so the engine will start without difficulty. If the exhaust valve opens late the timing gear may be moved a few teeth and again meshed with the gear on the crankshaft. The crankshaft is rotated again and the opening of the exhaust valve again noted. The closing point is next determined by continuing to turn the crankshaft. The exhaust valve remains open during the next upstroke of the piston and does not close till after the piston starts on the intake stroke. Right after the exhaust valve closes, the intake valve should open and remain open during the next down stroke of the piston, at which time the cylinder should fill with gas.

To facilitate timing it may be well to mark the flywheel at points to correspond to the position of the piston in the first cylinder when it is at the top of its stroke and similarly when it is at the bottom of the cylinder. These marks may be made with a center punch or steel stamp and should come directly opposite each other. They are of greatest value on engines with inclosed crankcase, as when the crankshaft is exposed, it is easy to follow piston movements by the position of the crankpin and connecting rod. The exhaust valve generally opens about 30 degrees crankpin travel ahead of the mark corresponding to the bottom position of the piston on the down stroke following ignition. The valve remains open the remainder of that stroke and the entire next stroke, closing a few degrees after the piston has started on the suction stroke. The inlet valve opens about 15 degrees late and closes about 10 degrees late. The exhaust valve thus remains open a period equal to about 220 degrees crankshaft travel, the inlet valve seldom remaining open more than 180 degrees. The ignition spark, with timing lever at center

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position on quadrant, should take place just when the piston reaches the end of the compression stroke.

Care of Piston and Rings.—Very often poor compression is caused by a defective condition of the piston or piston rings. If lubrication has been neglected and the cylinder has seized at any time, both the piston and cylinder walls will be found scratched and scored. Even if lubrication has not been neglected, but poor oil or an insufficient quantity has been used, the same scratches will be apparent though not to so large a degree. The piston rings may break, which will allow the gas to escape through the division between the broken parts. They may become gummed in their grooves so they do not spring out as they should and gas can blow by them. In cases where the piston rings are not pinned the slots in the rings may work in line and permit gas to escape through the series of openings.

Piston rings often lose their elasticity or spring, or they may wear to such an extent that they will not form an effective seal against the explosive pressure. In event of deterioration, the only method is to replace the rings with new members. If the piston rings do not work freely in the grooves, they should be removed from the piston and all burnt oil cleaned off. The carbon deposits which have collected in the grooves should also be removed before the rings are replaced. If the piston and cylinder walls are badly scored the only remedy is to have the cylinder bore ground out to a new surface and use a new piston member made to fit the enlarged bore. This will mean that new rings must be fitted as well as a new piston. Many believe that the cheapest way in the end is to secure an entirely new piston and cylinder from the makers to replace the defective members.

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Noisy Operation.—A number of power plant derangements are readily noted because they give positive indication of trouble by noises easily distinguishable by the untrained ear. Knocking or rattling sounds are usually the result of wear in the connecting rods or main bearings, though often a very sharp knock, such as might be attributed to a loose bearing, is due to carbon deposits in the cylinder or combustion chamber, premature ignition due to advance spark lever or a loose flywheel. Dry bearings are invariably indicated by squeaking sounds and whenever this signal of distress is heard the engine should be stopped immediately and oil applied to the parts which have indicated their dry condition.

Leaks produce whistling or blowing sounds; a sharp, definite pitched whistle denotes the escape of gas under pressure and is usually produced by a defective packing or gasket that is used between the cylinder and cylinder head or as a joint for the exhaust manifold. A blowing sound is caused by leaky packing in the crank case, worn main bearings or wear in the valve plunger guides. Grinding noises in the motor are usually caused by the timing gears and will be heard if these gears are dry or if they have become worn. Minor rattles often indicate nothing more serious than too great clearance between valve stem and their operating plungers, or wear in the valve plunger guides. Any loose driving connection anywhere on the engine will contribute its quota of noise and often a combination of sounds are produced that will be very annoying even if they do not indicate serious wear.

Adjusting Bearings.—The most fertile source of noisy operation is wear in the main bearings of the engine or looseness in the connecting rod bearings.

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The points where deterioration produces the most noise are clearly indicated at Fig. 163, which shows the bottom view of the top half of a four-cylinder engine crankcase. This shows clearly the five main bearings of the crankshaft, two of these members, that on the rear and the one next to it, having the bearing cap removed in order to show the shaft journals. Under the influence of the explosions the bearings in time tend to become

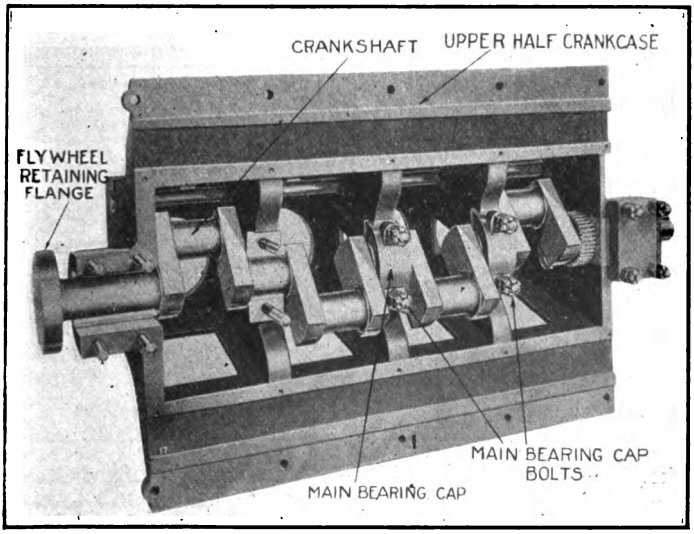

FIG. 163.—Bottom View of Crankcase With Bottom Half Removed to Expose Crankshaft and Main Bearings.

hammered down a trifle and lost motion exists between the crankshaft and the bearing bushes.

If the wear is comparatively slight it may be eliminated by removing some of the thin shims of sheet metal placed between the bearing caps and the lower portion of the box and replacing the caps. This will enable

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them to bed down closer to the crankshaft and the lost motion which produces the noise will not exist. If the bearings have worn to such an extent that removing the shims will not be sufficient, new brasses or bushings must be inserted in the boxes and scraped to fit the crankshaft. If the crankshaft is cut or scored, the journals should be smoothed with fine emery cloth before attempt is made to fit the bearings to the shaft.

A typical connecting rod in a disassembled condition is shown at Fig. 164 with the various parts separated

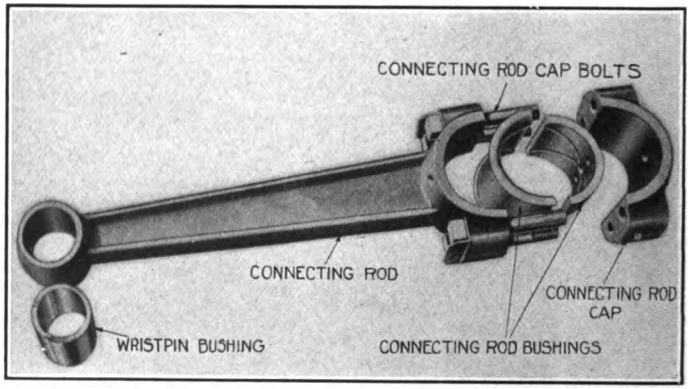

FIG. 164.—Connecting Rod of Gas Tractor Power Plant Showing Removable Crankpin Brasses.

in order that the construction may be clearly ascertained. It will be noticed that the small bushing which surrounds the wrist pin is a solid member pressed into the boss at the upper end of the connecting rod. If any wear exists at this point the old bushing should be forced out and replaced by a new member. The lower portion of the connecting rod which encircles the crank pin is provided with a split box composed of two white metal bushings that bed into the con-

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necting rod and the connecting rod cap, respectively. The two halves of the connecting rod lower end are usually separated by thin shims or liners, such as used in main bearings, and if the connecting rod is not very loose, lost motion may be e iminated by removing enough of the thin shims and then joining the parts together securely. If the connecting rod bushings are worn too much to permit refitting, they can be easily replaced by new members secured from the maker.

The average tractor operator is not apt to be a good enough mechanic to scrape in and refit a set of main bearings, but this process is not a difficult one to learn, the only requirements being that the workman shall

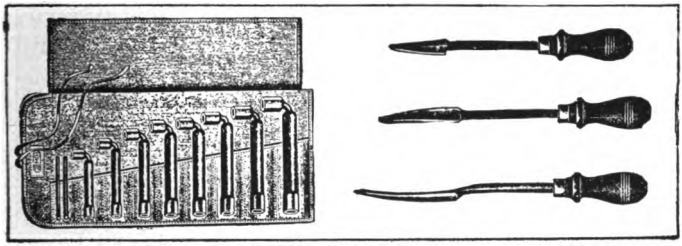

FIG. 165.—Tools That Facilitate Refitting of Bearings.

be reasonably careful, have the proper tools and be patient enough to fit the bearings properly. The tools shown at Fig. 165 will considerably facilitate refitting of bearings. The set of three scrapers shown will prove adequate for all sizes of bushings while the socket wrench set will make the constant removal and replacement of the bearing cap nuts a less difficult task than if the ordinary form of monkey wrench is used. When refitting the main bearings the first precaution is to clean the crankshaft thoroughly. Only attempt to fit one box at a time, as if more than one bearing cap is tightened it will be hard to tell which one is too

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tight. After the shaft and boxes have been cleaned, the main journals of the crankshaft should be coated with a very light, thin film of Prussian blue pigment which may be obtained in a collapsible tube at any paint store. The crankshaft is then dropped in the boxes which are held by the engine base and revolved a number of times in order that all the high spots on the boxes will have a chance to run against the shaft. When the shaft is removed the high spots will be indicated by specks of blue on the brasses.

Before again replacing the crankshaft, these high spots are scraped off by means of curved bearing scrapers. The shaft is again replaced and revolved so that it will indicate another set of high places. The scraping in process is continued on all of the lower boxes until the crankshaft has many points of bearings evenly distributed at each box. The caps are the next to receive attention. The shaft is allowed to remain in place and one cap is fitted at a time. The crankshaft journals are kept covered with Prussian blue, a new film being put on with the finger each time a test for high places is to be made. The fitting is started with either the front or rear main bearing cap which is brought against the shaft by means of the retaining nuts, until it is difficult to turn the shaft. The nuts are slacked up a trifle and the crankshaft turned. Part of the Prussian blue will be scraped off by the high points in the bearing caps and these are removed by the scraper and the fitting process continued until the bearing cap shows an equal bearing by a uniform distribution of color. The cap is properly fitted when the crankshaft does not turn unduly hard with the bearing cap retaining nuts bedded down firmly and the cap in firm contact with the engine base or the interposed

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shims of metal. Each cap is fitted in turn, and if the work is carefully done it will be found possible to turn the crankshaft over without much difficulty when all the caps have been properly replaced and no lost motion will exist between the caps and crankshaft.

The same instructions apply to fitting connecting rods, the test for high spots being made by the use of Prussian blue pigment and the trial to ascertain if the bearing clamps the shaft too tightly is made by rocking the connecting rods back and forth. The degree of resistance indicates the fit of the bearing. A connecting rod is usually considered properly fitted if it is not loose and yet will drop over slowly due to the piston weight when placed in a vertical position. Care should be taken not to adjust bearings too tightly, as this may produce sufficient heating to burn out the white metal bushings or score the crankshaft journals badly when harder materials, such as bronze, are used. Before replacing either connecting rod or main bearing caps for the last time, it will be well to use liberal quantities of cylinder oil to insure that they will be properly lubricated when the power plant is first started after the refitting process is complete.

Mixture Troubles.—Defective carburetion is usually indicated by misfiring or irregular operation. The common derangements of the components of the fuel system and the best method for their location follow: The first thing to do is to see if the fuel is flowing to the carburetor from the tank. This is done by disconnecting the feed pipe and seeing if the stream coming out is the full size of the orifice. If it trickles out slowly it is an indication that either the pipe is clogged with dirt or that there is an accumulation of scale, rust or lint at the strainer screen usually placed in tank over

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the gasoline discharge coupling. This may also indicate that there is not enough liquid in the tank. Insufficient fuel supply is sometimes due to the shutoff valve between the tank and carburetor having jarred either partly or wholly closed because of vibration. If the stream of fuel from the tank indicates that it is reaching the carburetor all right, that device should be examined to see if there is any dirt or water in the float chamber. The float chamber of most carburetors may be drained by a petcock provided for the purpose. Dirt may constrict the passage between the flow chamber and the spray nozzle and very often the fine holes or spray openings in the latter may become blocked up by particles of foreign matter. The float may be binding and the gasoline needle valve regulating the supply opening in the bowl may stick to its seat. Any of these conditions would reduce the supply of fuel and the engine would not receive sufficient quantities of properly proportioned gas.

Some of the conditions that will produce poor mixture are: The air valve spring may be weak or broken, the gasoline or fuel adjusting needle may be loose and jar out of adjustment, the air valve spring adjusting nuts may be a poor fit on the valve stem and adjustments will not be retained, air may leak in through leaky joints of the inlet manifold or through holes of a porous casting; or the valve stem may have worn enough in the guides so air is drawn into the mixture through the worn inlet valve stem guide bushings. Any foreign matter in the fuel will cause irregular operation because the standpipe bore may be partially constricted and not allow enough fuel to reach the mixture.

If clouds of black smoke are expelled from the exhaust pipe it indicates that the fuel supplied the mixture is

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excessive and the supply should be reduced by screwing down on the needle valve in carburetors where this method of regulation is provided. If no needle valve is used the fuel proportions may be reduced by altering the fuel level in the float bowl. A pronounced "popping" in the carburetor means that the mixture contains too much air. If this is not due to air leaking in through worn valve guides or leaky manifolds it may be overcome by screwing in the auxiliary air valve adjustment so the valve does not open so much or by slightly increasing the fuel supply by opening up the regulating needle. The exhaust gas will be free from any objectionable odor and will be clean if fuel is not burnt in excess. The character of the mixture may be judged by the color of the flame issuing from the exhaust pipe if the engine is run with an open throttle after dark. A red flame indicates too much gasoline, and a yellowish one shows an excess of air. A pronounced blue flame such as given by a gas stove or gasoline stove burner will indicate the properly proportioned mixture.

Ignition System Derangements.—When a battery ignition system is provided and the engine does not run regularly the first thing to look for is to see if there is a spark at the spark plugs. These members are removed from the cylinders and are then again coupled up to the secondary wires. They are laid on the cylinder castings in such a way that the bushing intended to be screwed into the cylinder is in good metallic contact but the insulated terminal at the upper end out of contact. The engine is then turned over slowly by hand and the spark plugs watched to see if there is any spark between the points. If there is no indication of current flow the following may be looked for: A broken wire anywhere in the primary circuit, a defective

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ground connection, loose battery terminals, broken battery connections, lack of current at the battery. The method of testing dry cells is extremely simple and is outlined at Fig. 166. Each cell is tested in turn by a small watch size testing instrument which indicates the available current strength in amperes. Any dry cells that read below six or seven should be rejected and, in fact, it will be well to replace dry cells unless they indicate at least eight amperes.

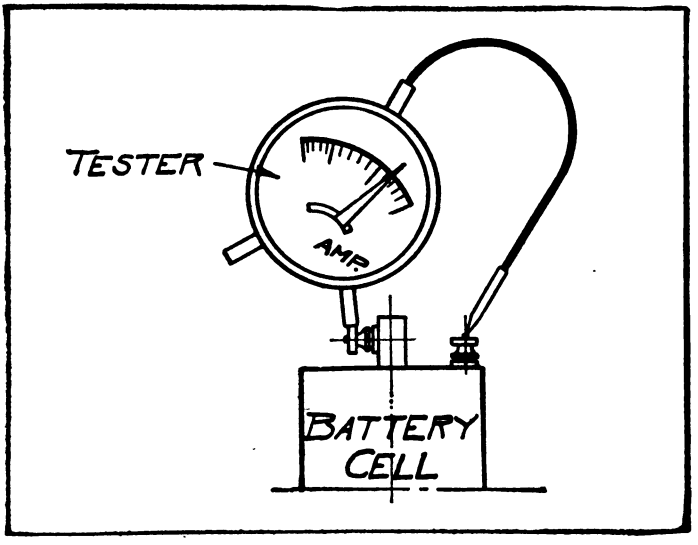

FIG. 166.—Method of Testing Capacity of Dry Cell.

If there is no spark at the plugs but the spark coil vibrators buzz properly this shows that the primary wiring is all right and that the fault must be looked for either in the wires comprising the secondary circuit or at the spark plugs themselves. Spark plugs may be rendered inoperative by cracked insulation or by deposits

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of carbon around the electrode. Secondary wires sometimes break or may become oil soaked or have the insulation worn away, either of which permits the current to become grounded to some metal part of the motor. The electrodes of a spark plug may have burnt away enough so the gap is too great or the points may be too close together. If there is no vibration at the spark coil the trouble may be due to broken timer wires, burnt or pitted vibrator contact points, vibrator out of adjustment, or poor connections at the commutator or timer.

If a low tension magneto is fitted as an auxiliary supply of current, about the only thing that will cause failure of current generation outside of slipping or broken driving connections is brush trouble. The commutator sometimes becomes covered with an oil glaze or the brush holders may become fouled with old oil. Either of these conditions interferes with the flow of the current. The brushes may become worn so they no longer bear on the commutator and the current generated by the armature cannot be collected and sent to the outer circuit. Obviously any derangement of the driving connections will interfere with current generation because the armature will not be turned sufficiently regular or at the proper speed.

If a high tension magneto is fitted and no spark is produced at the plugs the following defective conditions should be looked for: Broken secondary wires, current collecting brushes or distributor brush not making contact, contact points of the make-and-break device may be out of adjustment or covered with oil; the wiring may be attached to wrong terminals; the distributor filled with metallic particles, carbon dust or oil accumulations; the distributor contacts may not

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be making proper connections because of wear or a defective distributing brush or more serious derangement may exist, such as defective windings or condensers, which fortunately are of extremely rare occurrence.

Cooling and Lubrication Group Faults.—Owing to the simplicity of the cooling systems ordinarily used on gas tractors they are not liable to give trouble if the radiator or tank is kept full of clean water and the circulation is not impeded. The most common troubles producing defective cooling are due to impeded water circulation. A radiator may become clogged with rust or sediment and the piping or water jackets sometimes become filled with scale that tends to retard the flow of water. If the water pump or its driving means fail, circulation will not be positive and overheating will result, as is also evident if the cooling fan belt breaks or slips.

When rubber hose is used in the circulation system, this may deteriorate inside and the area of the inside passages become reduced due to particles of rubber hanging down. The cooling system is often apt to overheat after anti-freezing solutions of which calcium chloride forms a part have been used, as crystals of the salt may collect in the radiator, piping or water jackets. These crystals can only be dissolved by chemical means when in inaccessible places, but where the construction permits they may be removed by scraping. Overheating is sometimes caused by rich mixture and sometimes by defective lubrication.

When the oiling group is not working properly the friction between the parts of the mechanism usually produces heat. Poor lubrication usually results from: Not enough oil in the engine crank case or mechanical oiler, oil of poor quality, broken or clogged oil pipes, broken oil pump or defective oil pump drive. The

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oil supply may be reduced by defective inlet or discharge check valves at a mechanical oiler or by worn pump-plungers in that device. A clogged oil passage or pipe leading to an important bearing point will result in loss of power and overheating because the oil cannot get between the working surfaces. Much of the trouble caused by defective oiling may be prevented by using only the best grades of lubricating oil, and lubricants

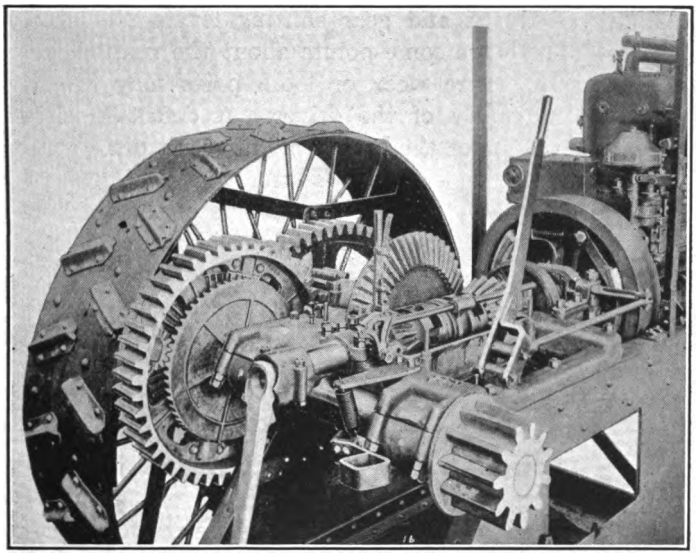

FIG. 167.—Assembly View of Reversing Gear, Main Drive and Differential Gearing of "Twin City 40" Gas Tractor.

of poor quality will cause friction and overheating even if all parts of the oil system are working properly. If a mechanical oiler becomes inoperative or its driving means fail while the tractor is in the field, the engine may be kept in operation by putting enough oil in the

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crank case so the connecting rods will dip into it as the crank-shaft revolves.

Running Gear Derangements.—Running gear trouble and its cause is usually apparent as soon as it happens. If a clutch refuses to hold or if a shifting gear will not engage it is obviously due to some mechanical derangement that can be fixed as soon as located. A typical transmission system is shown at Fig. 167, and in this various driving members and the bearings as well as clutch and gear shifting levers are clearly shown. There are some points about the running gear of a tractor where wear or loose parts may directly concern the safety of the driver. A defect in either the steering gear or the brakes might result disastrously to the operator in event of failure.

One of the most important members of the transmission system, which the writer will consider in connection with the running gear assembly, is the clutch, and derangements of this member will affect the efficiency of the entire assembly. The most common defects are failure to engage properly, slipping under load and "grabbing," which is the result of too sudden engagement. The former condition is usually the result of wear of the wood friction blocks, and may generally be easily compensated for by screwing out on the adjustment provided so the clutch blocks may be brought more forcibly into contact with the clutch-ring when the actuating lever is operated. Slipping may be caused by charred or broomed out friction blocks, and when this condition is evident the best remedy is to replace these members.

If the clutch engages too suddenly it is generally due to the adjustment having been taken up to a point where the hand lever need only be moved a very small

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amount to produce clutch engagement. This can be prevented by proper attention to the clutch adjustments. If a clutch shifting collar is worn too much, or the small pins in the yokes of the rods connecting the clutch operating bell crank with the hand lever are worn, it may take too much movement of the handle to set the clutch. This defect can be easily remedied by replacing the worn members.

Not much trouble is produced by the gearing of a tractor until the gear teeth become worn. When shifting members are used to obtain changes of speed there may be some difficulty met with in sliding these into mesh if the edges of the teeth are burred over, and this often causes trouble on the teeth of the positive jaw clutches used in connection with reversing gears. Difficulty in clutch or gear shifting is sometimes due to binding of the control levers or operating rods because of accumulations of rust or dirt. Driving gears do not give much trouble, though when the teeth become worn or the bearings in which the shafts run become loose, there will be considerable noise and rattle while the gearing is in action.

Where chains are used for driving, these for the most part are run without covering of any kind, and as the action of the dirt and gravel is to combine with the grease on the outside and form an abrasive, considerable wear will result if the chains are not kept clean. To obtain proper results from driving chains, they must be kept in proper adjustment. A chain that runs too loose is apt to climb the teeth of a sprocket, whereas if it is adjusted too tightly they are liable to break, especially if the sprocket teeth are worn hook shape

Not much trouble is caused by bearings if these are kept properly oiled. The same rules previously given

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for fitting engine bearings apply just as well to the plain bearings used for supporting the differential cross shaft or the rear axle. In some tractors anti-friction bearings are used, these being of the ball or roller type. It is important that the oil used with bearings of this nature contains no acid, and care should be taken to prevent dirt or grit from entering the bearing housings.

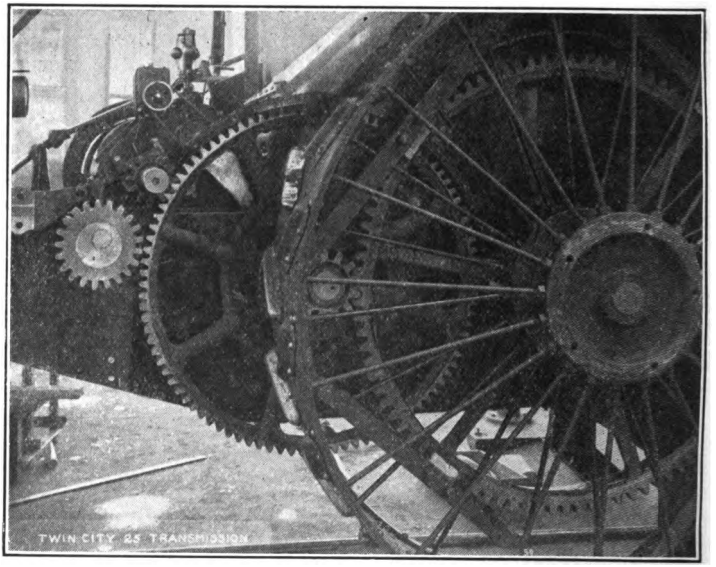

FIG. 168.—Driving Gears of "Twin City 25" Gas Tractor.

Grinding sounds in gearing are usually produced by gears meshing too deeply, while worn gears usually manifest their defective condition by rattling. The wheels should be tested from time to time to see that their bearings are not worn unduly by jacking up the tractor frame and turning or shaking them after they

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are relieved of the machine's weight. With a one piece front axle the important point to watch is the supporting pivot, and this should be kept clean and well oiled at all times. Steering chains should be examined frequently to make sure that no links have started to pull apart and that they are in proper condition. When an Ackerman type axle is used, the steering knuckles should be looked over to make sure that the spindle bolts are right and at the same time the various joints of the drag link and tiebar should be carefully examined for any lost motion. It will be well to encase all of the joints of a steering system in small leather bags packed with grease, because if these are kept well lubricated and protected from grit, very little wear will exist at these points.

The brake should be always kept in proper adjustment. The means prov ded are available on inspection. If the brake fails to hold properly the friction facing should be examined to see that it has not become worn and the various portions of the operating levers should be inspected to see that there are no weak points or worn parts liable to give out at a critical time. A brake should not be adjusted too tightly, because if it bears on the brake drum when in released position it will cause friction and produce loss of power. At the other hand if the brake is not adjusted sufficiently tight a full movement of the operating lever will not apply the brake tight enough to stop the tractor.

An important point to observe when the wheels are of the built-up construction is that the spokes are kept properly tightened, as one or more loose spokes in a wheel will seriously reduce the strength of the assembly. A typical built-up wheel, in which the spokes are screwed into the cast hub and held in place by

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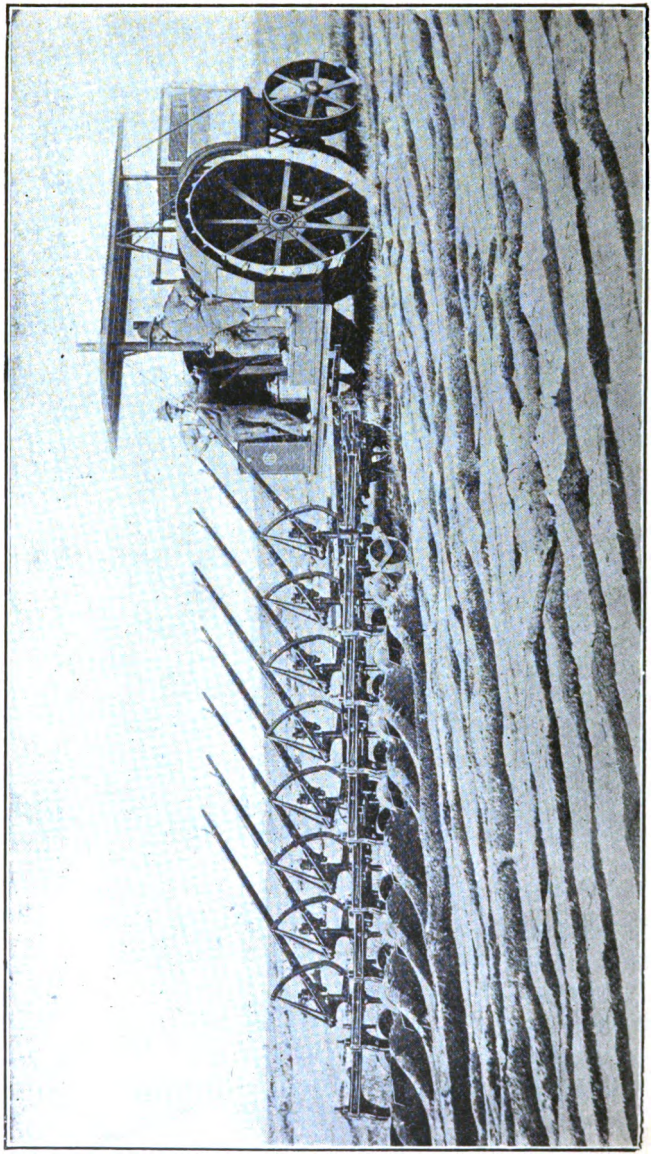

FIG. 169.—I. H. C. Gas Tractor Pulls Eight Bottom Hand Lift Gang Plough With Ease. A Simple Hitch of Marked Utility.

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lock nuts, is shown at Fig. 168, and to tighten these members the lock nuts must be slacked up and the threaded end of the spoke screwed into the hub more tightly with a Stilson or pipe wrench, then locked in place with the lock nut.

Tractor Hitches.—The use to which the gas tractor has been more widely applied than any other is in furnishing power for pulling ploughs. The hitch required is relatively simple, as the gang of from six to twelve ploughshares is attached to the tractor drawbar as a compact unit. The only precaution to observe is that the chains by which the plough is pulled should be attached to the drawbar in such a way that an even draft will be obtained and the ploughs trail along directly back of the tractor. If a large number of bottoms are provided and the total width of the gang exceeds that of the tractor, the plough frame must be attached to the drawbar so that the ploughshare that is in the furrow last cut will be about on a line with the nigh tractor driving wheel outer edge. Under these conditions it is not possible to have the plough pull as evenly as when a lesser number of shares are used, because those which project beyond the tractor cannot fail to produce a side draft.

Two common forms of the gang plough have been devised for use with the gas tractor. That at Fig. 172 shows a conventional five bottom gang with hand operated levers to control the depth of cut and the action of the ploughshares. Most power ploughs are provided with a wheel or colter which is placed just in advance of the plough point so it will be raised automatically over a stone or other impediment that might damage the plough. A platform of planks is placed over the forward portions of the frame so that a man can stand

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FIG. 170.—These Three Gas Tractors Are Doing the Work of 120 Horses and but Three Men Are Needed to Guide Them.

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on the plough and control the levers as desired. As this means that two men must be employed in ploughing, another form of gang plough which is known as the "self-lift" has been devised to make it possible for the engineer of the tractor to control the ploughs directly from his position on the tractor platform.

FIG. 171.—Holt Caterpillar Tractor at Work Ploughing Deep Furrows.

The Avery "self-lift" engine gang plough, having ten ploughshares, is shown at Fig. 173. At Fig. 174 the method of raising the ploughshares is clearly outlined. A special broad tread wheel having grouters to insure

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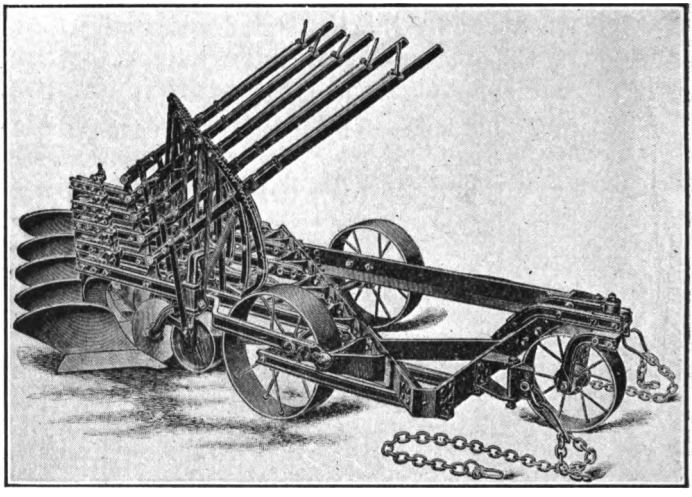

FIG. 172.—Typical Hand Lift Five Bottom Gang Plough Adapted for Use With Traction Engine.

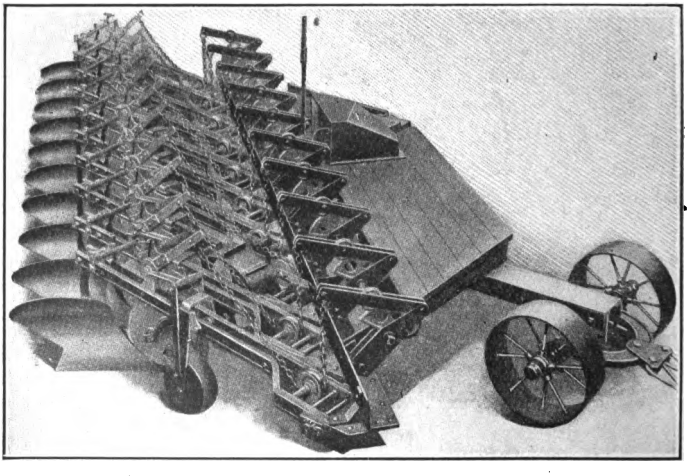

FIG. 173.—Avery "Self Lift" Ten Bottom Gang Plough Makes It Possible for Engineers to Control Ploughs Without Leaving Tractor Cab.

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positive drive is mounted beneath the plough frame and drives a cross shaft by means of chain and sprocket connection. A series of pivoted bellcrank arms to which the ploughshare beams are attached by chains are utilized in lifting them. The method of operation is simple. A trip lever is pulled in such a way that a clutch is engaged. This connects the driving sprocket to the short shaft on which the bevel pinion is mounted that meshes with the bevel gear driving the eccentric

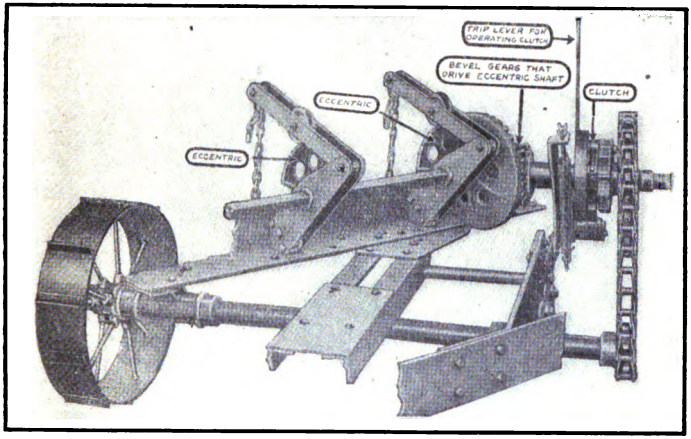

FIG. 174.—View Showing Mechanism of Avery "Self Lift" Plough.

shaft. As the gears turn, the eccentrics pass under the rollers in the plough lifting cranks, and in this manner the ploughs are lifted directly by means of power instead of by the usual hand lever.

Many traction engine operators, especially those who have to cultivate large areas, arrange to draw a number of machines at the same time and thus perform different operations on a certain strip of ground by going over

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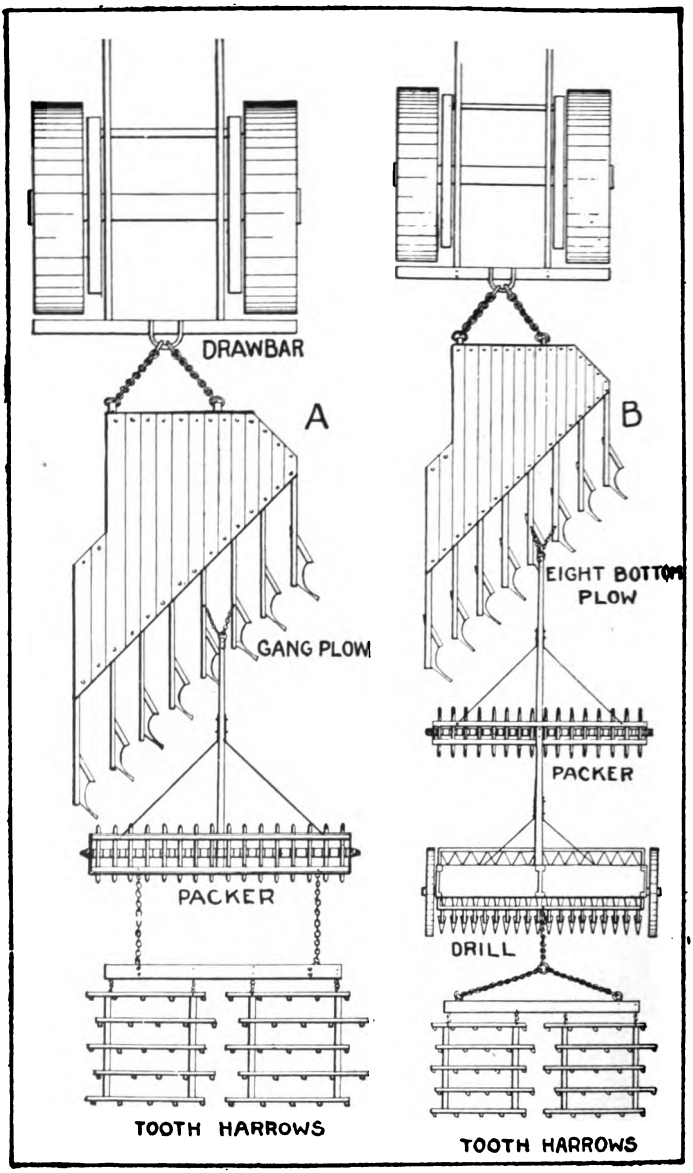

FIG. 175.—Plan Views of Combination Hitches That Save Time and Labor. *A*—Plough, Packer and Toothed Harrow. *B*—Plough, Packer, Drill and Toothed Harrows.

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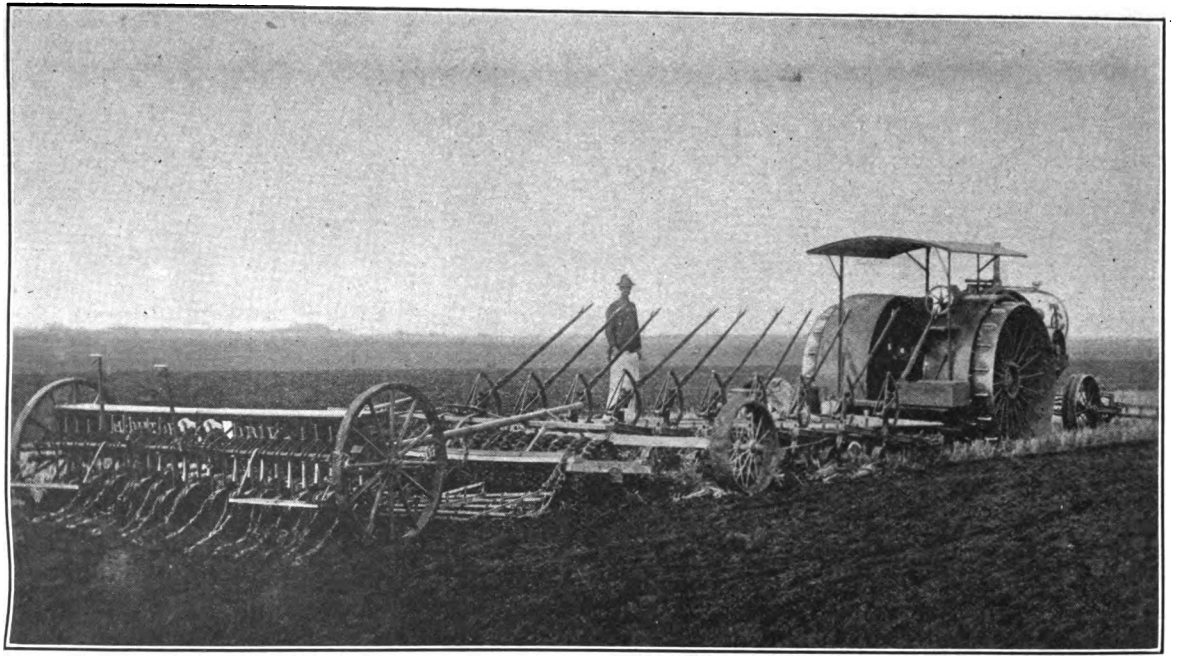

FIG. 176.—Ploughing, Packing, Harrowing and Seeding This Ground Accomplished in One Operation. "Twin City 40" Gas Tractor Furnishes Power When Utilized in This Manner at Extremely Low Cost.

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it only once. At Fig. 175-A a hitch is shown in which an eight bottom gang plough is attached directly to the tractor drawbar. A packer is attached to the plough and tooth harrows are drawn in turn from the packer. By utilizing machines in this manner the ground is broken, packed, and harrowed at one time. Another hitch which is very similar is shown at **B.** In this a drill is interposed between the packer and the tooth harrows and thus a strip of ground may be

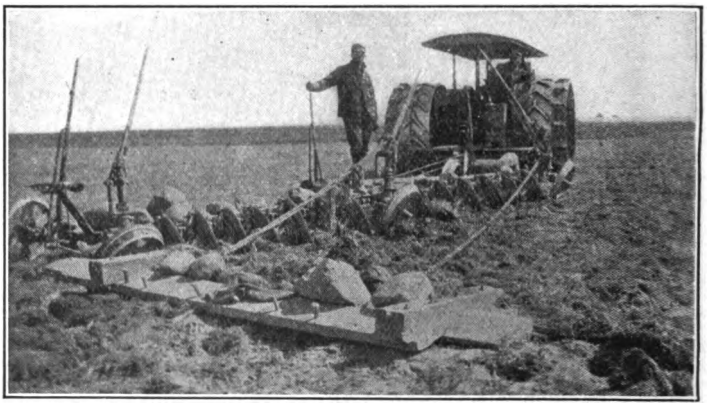

FIG. 177.—Outfit of Berland and Lee, Brady, Mont., Ploughing With Disc Plough and Packing With Stone Drag.

ploughed, packed, seeded, and harrowed in practically one operation. The illustration at Fig. 176 shows a practical application of a plough, packer, tooth harrow, and drill, actually in use in the field. That at Fig. 177 clearly demonstrates the utility of a disc harrow or plough and stone drag packer combination.

The number of auxiliary machines that can be used in connection with the plough depends largely upon the power of the tractor available. Some of these have

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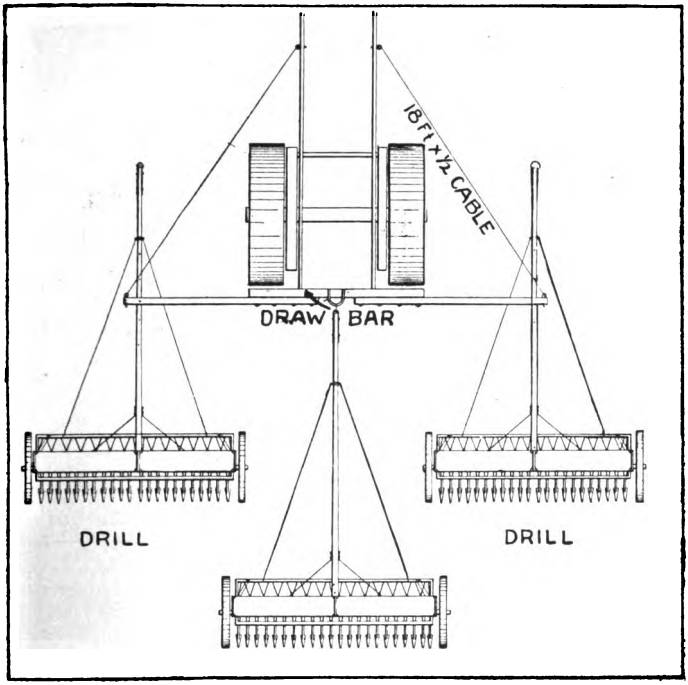

FIG. 178.—Simple Three Drill Hitch Easily Made by Any Farmer.

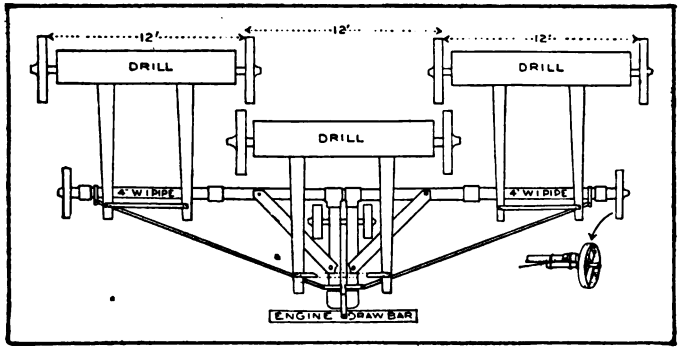

FIG. 179.—Wrought Iron Pipe Drill Hitch for Three Drills.

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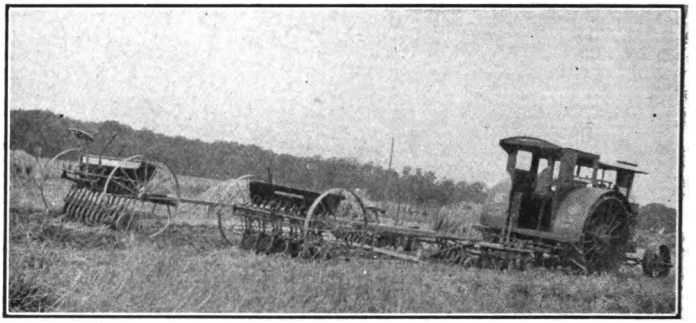

FIG. 180.—Practical Application of Drill Hitch.

just barely enough to haul a six or eight bottom gang plough without increasing the load by adding other machines. If the tractor has a wide margin of power it is, of course, possible to operate other farm imple-

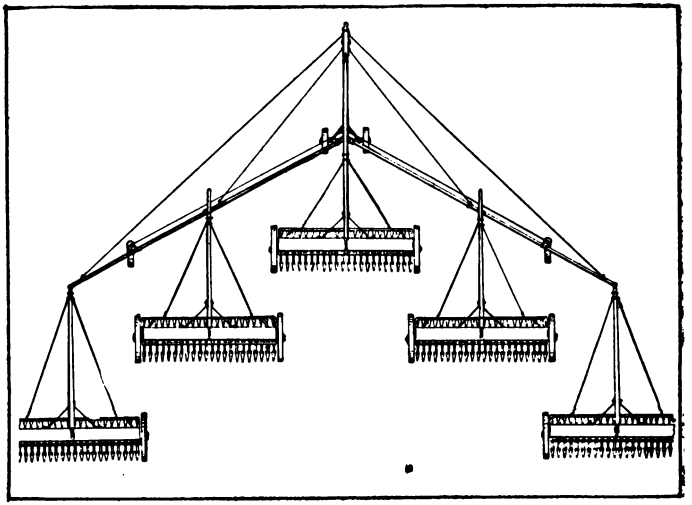

FIG. 181.—Hansmann Patent Five Drill Hitch Very Useful in Seeding Large Areas as It Covers a Strip Sixty Feet Wide.

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ments without straining the tractor. The ordinary eight-foot disc harrow, which weighs about six hundred pounds, requires four horses to draw it. This means that it will take approximately 600 pounds pull for a tractor to draw it. A twenty-foot drag harrow requires the same power as an eight-foot disc harrow and the same pull will also operate a ten-foot wide clod crusher. As three horses will usually handle a twelve-foot disc

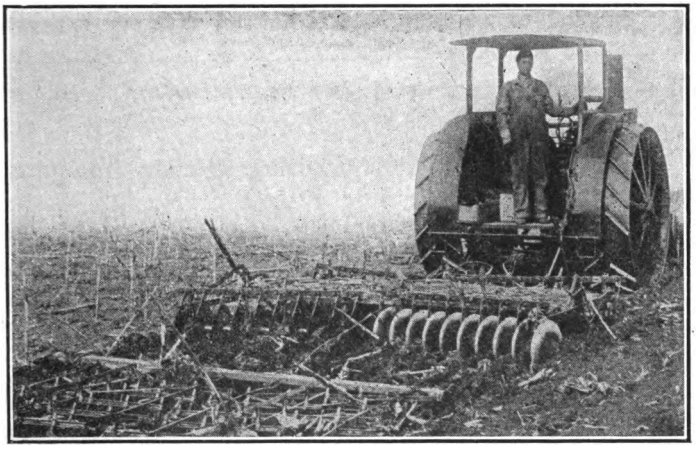

FIG. 182.—Avery Gas Tractor Outfit Owned by D. M. Circle, Kiowa, Kansas, Pulling a Double Disc and Lever Tooth Harrow.

drill, which seeds a strip eight feet wide, a pull of 450 pounds will be needed for each drill hauled.

An easily made and simple drill hitch is outlined at Fig. 178. The method of attaching the drill is so clearly shown that further comment is not necessary. The ingenious farmer is often able to make hitches for use in connection with a gas tractor by utilizing odds and ends that are found on any farm of any pretensions.

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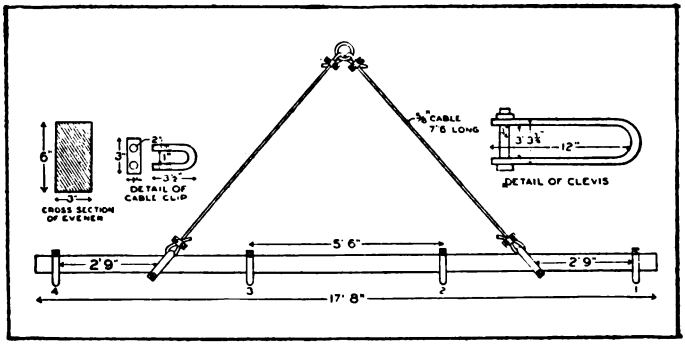

FIG. 183.—Details of Easily Constructed Harrow Hitch for Four Ten Foot Disc Harrows.

At Fig. 179 a method of utilizing wrought iron pipe and fittings so that three 12-foot drills will obtain equal draft from the tractor drawbar is outlined. An old wagon axle is cut in half and one wheel is attached at each end of the long four-inch pipe that forms the basis of the attachment. The practical application of a disc and drill combination is shown at Fig. 180.

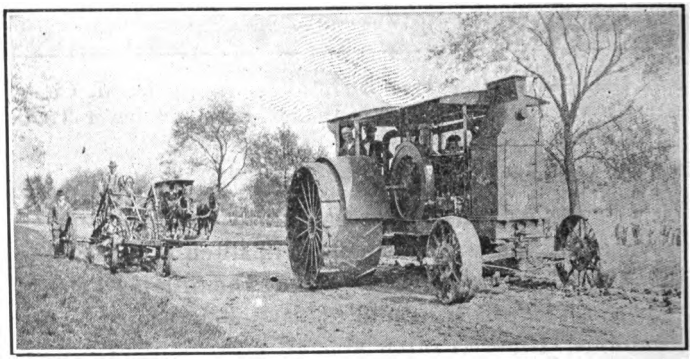

FIG. 184.—Practical Application of I. H. C. "Mogul" Tractor in Road Grading Work.

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When one considers the rapid growth of the gas tractor industry it is but natural to assume that a number of attachments would be devised for use with traction engines. That shown at Fig. 181 is the Hansmann five-drill hitch, which makes it possible for a tractor of sufficient power to pull five 12-foot drills and thus seed a strip 48 or 50 feet wide. An easily made harrow hitch, which will enable the tractor to pull four 10-foot disc harrows, is clearly depicted at Fig. 183. The draft

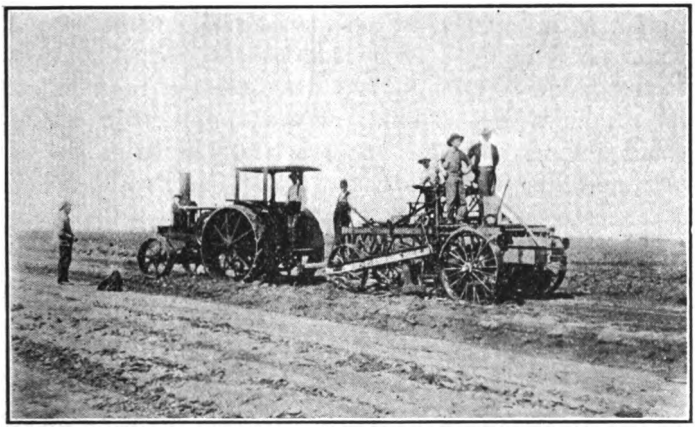

FIG. 185.—Avery Gas Tractor Pulling Western Wagon Loader and Elevator Grader.

bar of this device is composed of a length of 3″ x 6″ beam about 18 feet long. Four clevises are spaced along this evener bar. The bar is hauled by two 5-8″ steel cables, secured to a ring at one end and to clevises attached to the beam at the others. The ring is attached to the center of the tractor drawbar or in the line of pull if the harrows are drawn by a gang plough or follow any other implement. The details of the

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device are clearly shown and should be easily followed by any one of average mechanical ability.

Utility and Uses of Modern Gas Tractors.—The gas tractor offers many advantages in road construction and they are rapidly replacing the steam tractors formerly widely employed for this service. A convertible road roller-tractor combination is practically three machines in one, inasmuch as a simple change will convert the tractor to a road roller and *vice versa* and the machine can be used practically all the year round, as it can be utilized for hauling and belt work when not employed as a road roller. Economy is a strong point in favor of the gas operated road roller. As machines of this kind carry a supply of fuel and cooling water sufficient for practically a day's operation, no water wagon or coal wagon is needed to act as a tender as is necessary with the steam tractor.

A hitch by which a powerful enough gas tractor may be utilized to haul three road scrapers or graders at a time is clearly outlined at Fig. 186. This makes it possible to finish a large amount of work in one trip, as practically the entire width of the average roadway may be treated at the same time. The machine nearest the ditch line is attached directly to one end of the drawbar by means of a pole while the others are pulled by half-inch steel cables as indicated. The method by which the road scrapers are made to follow the tractor is also clearly shown. The same hitch as outlined would be practical with any other machine of which a number must be hauled at the same time, such as harvesters, etc.

The marked advantage of the gas tractor in road work is that the change speed gear feature found on most gas tractors enables them to do very heavy scrap-

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ing. By operating on one of the lower speeds a scraper blade full can be handled both on the level and when ascending hills, and it is never necessary to stop the machine and drop part of the load as is the case with a horse-drawn scraper when a heavier cut is taken than can be carried through by horses. When a tractor is used for road work the character of the work is always better than when horses are employed, because there are no irregularities in the cut as are invariably present when a scraper is drawn by animal power.

The lower cost of operating a road scraper by tractor as compared with the cost of doing this work by horses is probably the greatest point in favor of the gasoline tractor. The road commissioners of a New York town

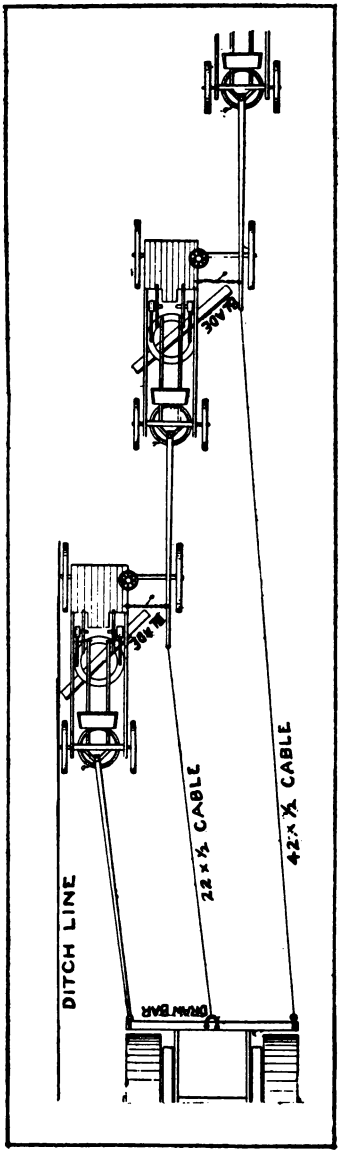

FIG. 186.—Practical Hitch for Pulling Three Road Scrapers Simultaneously.

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owning and operating a gas tractor state that the weekly expense when using six horses on the road machine has been $84.00 per week (including two-horse team hire at the rate of $4.00 each per day). They state that when operating the scraper by means of the tractor they accomplish one-third more work at a total weekly expense, including cost of gasoline, cylinder oil and operators, of $36.00, or a net saving of $48.00 per week plus one-third more work. To reduce this to the basis

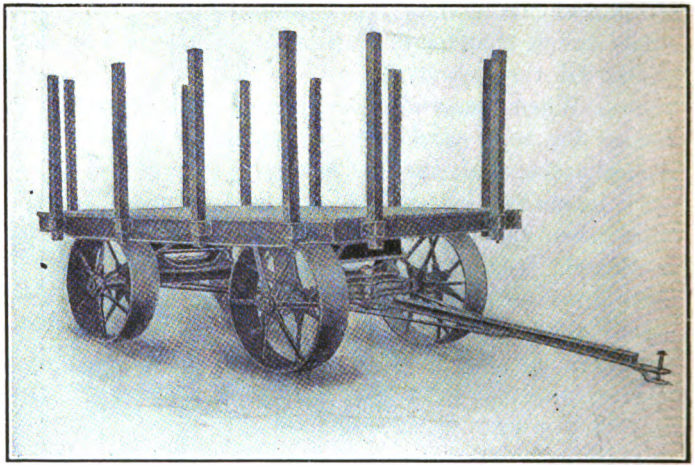

FIG. 187.—Special Wagon Adapted to be Used in Train Hauled by Gas Tractor.

of the cost for an equal amount of work, the hire of one additional team should be added, in which case the saving effected by the tractor is $72.00 per week. These figures cover the total cost of the work based on actual working conditions throughout the season (but not including interest and depreciation on machin-

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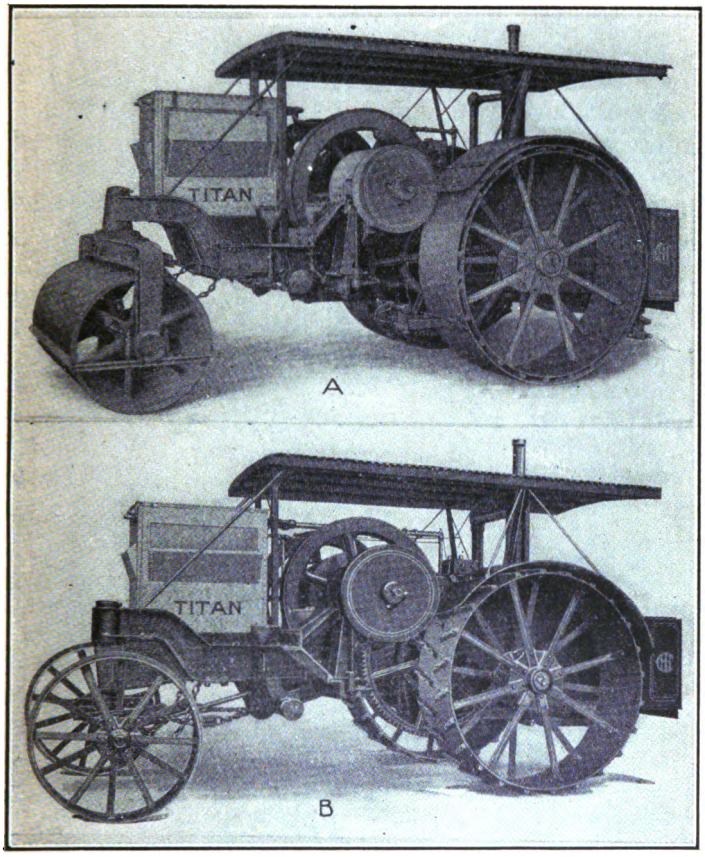

FIG. 188.—Combination Road Roller and Tractor, an Extremely Useful Machine for General Contractors or Municipal Use. *A*—Machine With Roller for Steering and Auxiliary Rims on Traction Members. *B*—Roller Removed From Front and Wheels Substituted, Making Practical Tractor for Road or Field Work.

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ery), the quality of the work being better than would be obtained by horse power.

The tractor referred to has also been used by the town chiefly for hauling gravel and crushed stone and doing other work of this nature, but in this particular instance has, during the late fall and winter, been a source of revenue to them as it has been rented to private parties for operating machines by belt power and also for ditching.

A tractor can be used successfully for hauling, and under average conditions on dirt or gravel roads, 20,000

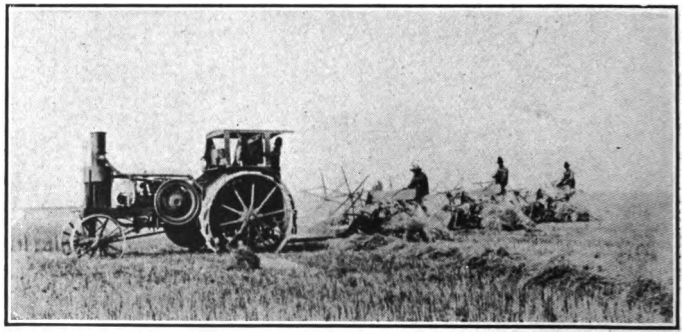

FIG. 189.—Harvesting With Avery Gas Tractor in North Dakota.

pounds, exclusive of the weight of the machine, can be hauled with a tractor of but 15 horse-power. On macadam roads, or good gravel roads, the hauling capacity is, of course, increased. As a rule, the character of the road surface greatly affects the hauling capacity. On a plank road but 100 pounds draft per ton hauled is necessary. Upon macadam road it will require from 150 to 225 pounds draft to haul one ton. The amount of power necessary increases to about 300 pounds per

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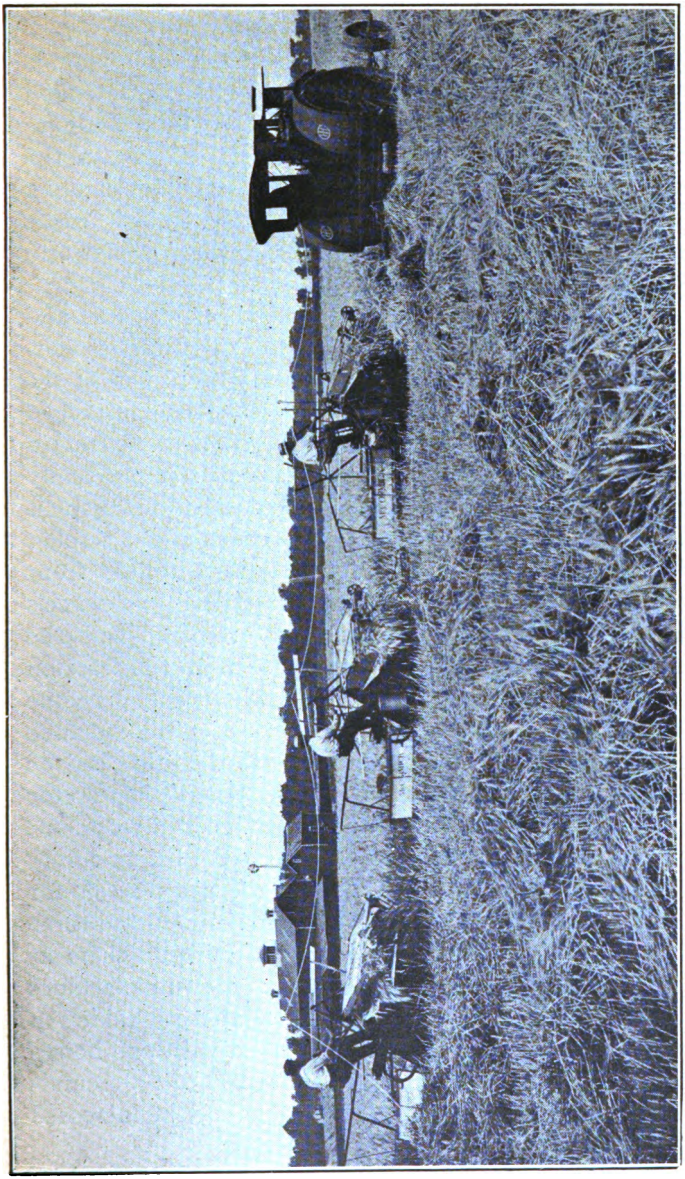

FIG. 190.—I. H. C. Gas Tractor Pulling Three McCormick Harvesters.

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ton on a gravel road and an average of about 400 pounds pull per ton on a common dirt road. Wagons intended to be pulled by tractors are of special form and are made so they can be coupled up in a train. As the width of wheels has material bearing upon the hauling capacity, most wagons adapted for use on soft roads have wide wheels. Such a vehicle with a platform body is shown at Fig. 187.

The construction of a combined gas tractor and road roller is clearly shown at Fig. 188. The view at **A** shows the roll in place under the front end of the machine and the auxiliary smooth steel tires attached over the grouters of the driving wheels. A tractor designed for use either as a road roller or tractor usually has a different method of front suspension than is commonly employed on tractors in order to use a roller of larger diameter than usually allowed for the front wheels. At **B** a one-piece axle carrying two wheels has been substituted for the roll assembly and the smooth steel tires have been removed from the traction members so that the grouters on the wheels again become effective. This makes possible the use of the machine as a tractor. The change from one to the other can be readily effected on the road, so the general contractor finds the combination machine a very good investment.

With the development of the successful binder hitch, it has been found practical to use the gas tractor for power in harvesting. Six-foot binders require from three hundred to five hundred pounds draft to pull them at a speed high enough to do good work. Mowing machines without binder attachment and capable of taking a five or six-foot cut are usually operated with two horses and therefore require a draft of about 250 to 300 pounds when hauled by a tractor. This value may be increased

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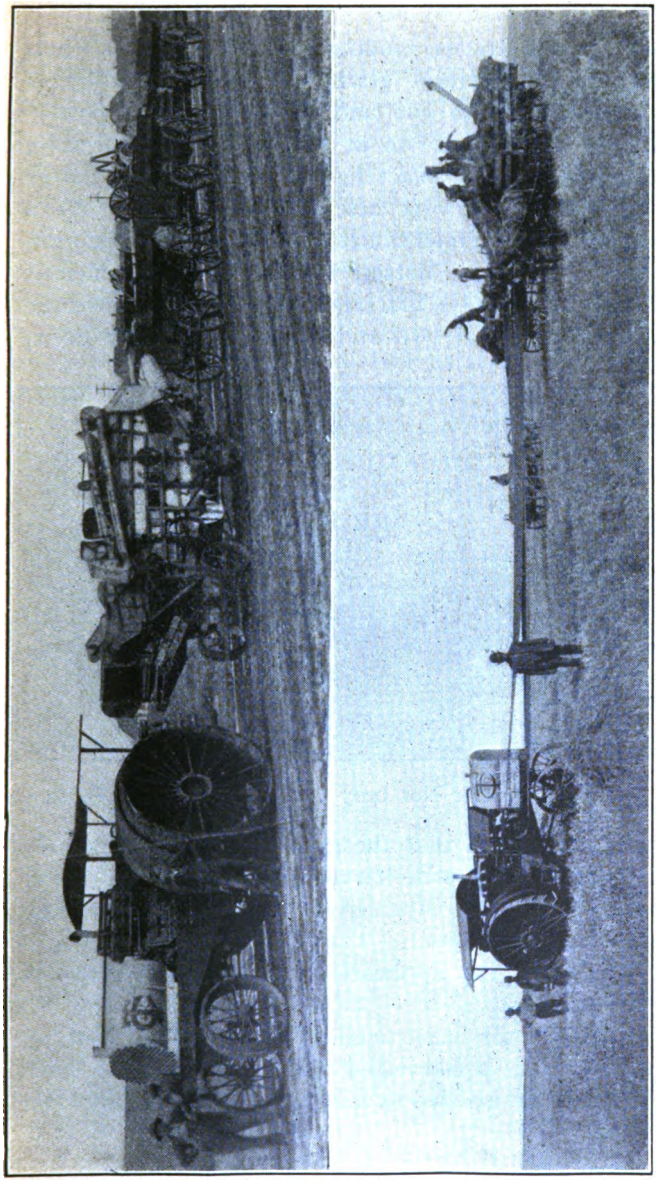

FIG. 191.—The Threshing Outfit Entrained Ready for Trip to Destination in Upper View. Outfit at Work in Field in Lower View.

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largely by dull knives, binding or tight boxes, or when cutting highly resistant grains or grass. Timothy is the hardest crop to cut and takes the most power. As almost all mowers run at speeds that are variable, it is difficult to give exact figures regarding the power consumption of mowing machines or binders. As a high speed must be maintained on a binder, it is common practice to use three horses, whereas two are sufficient for the mower. As the machines work to best advantage at a speed of about two and one-half miles per hour,

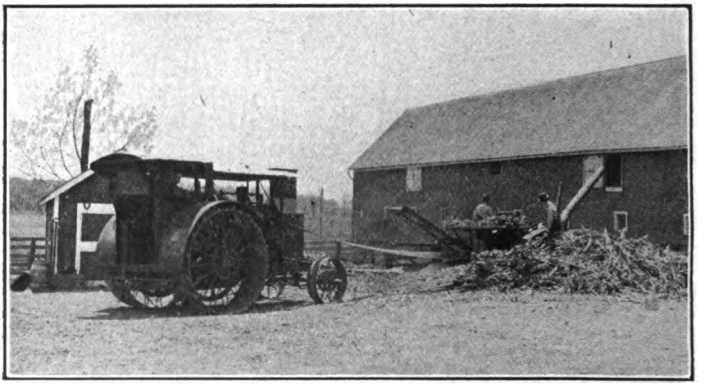

FIG. 192.—Gas Tractor Not Only Cuts but Stores the Fodder.

it will be apparent that the gas tractor is particularly well adapted for use in harvesting, as even the lower powered forms are capable of pulling three mowing machines at this speed. The views at Fig. 189 and Fig. 190 show the application of the gas tractor in harvesting work.

The gas tractor is particularly suitable for threshing after the grain is harvested, owing to the ease with which it can be utilized as a stationary power plant for

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work with the belt. The advantages in threshing have been considered at length in one of the earlier chapters, so it is merely necessary in this instance to briefly enumerate its advantages. At Fig. 191 an entire threshing outfit is shown ready for the road. The gas tractor can haul the threshing machine and the attendant train of wagons any distance, and when the scene of activities is reached it is but the work of a few moments to connect the tractor with the machine to be operated by means of a long driving belt as shown in the lower portion of the illustration. It will be apparent that the tractor is not only capable of hauling the implements and wagons necessary to any point, but it can also be utilized successfully for driving the machinery when it reaches its destination.

The power needed to operate various forms of machines under belt as given by the International Harvester Company follows:

MACHINE.	HORSE-POWER.
4-Roll Deering Husker and Shredder	12
6-Roll Deering Husker and Shredder	15
4-Roll McCormick Husker and Shredder	12
6-Roll McCormick Husker and Shredder	15
8-Roll McCormick Husker and Shredder	20
10-Roll Plano Husker and Shredder	20
24″ x 40″ Thresher	15
28″ x 44″ Thresher	20
28″ x 48″ Thresher	20
32″ x 52″ Thresher	25
36″ x 56″ Thresher	25
4-Hole Keystone Sheller	12
6-Hole Keystone Sheller	12

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As the ordinary tractor power plant will develop its full brake horse-power when used in belt work it will be apparent that even the lighter traction engines may be used successfully for operating the machinery that must be run by belt. The utility of the tractor for this purpose is clearly indicated at Fig. 192. Here the machine has been placed outside of the barn and convenient to the material to be cut and elevated into the loft. The tractor is run to where the work is to be done and a simple belt connection with any machine serves to drive it.

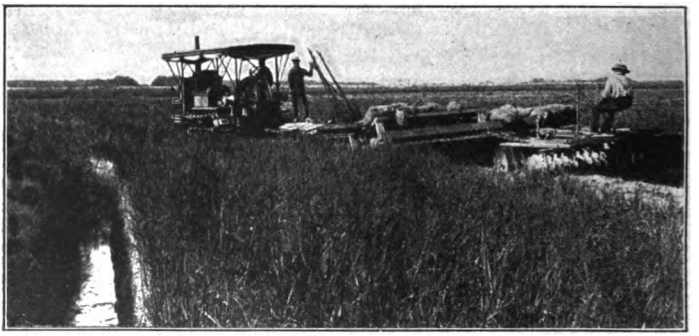

FIG. 193.—Holt Caterpillar Tractor Demonstrates Its Worth In Swampy Ground.

The tractor may often be used under conditions that on first consideration would seem impossible. At Fig. 193 the utility of the Caterpillar Tread Tractor in swampy ground is clearly demonstrated and it should be remembered that on land of this nature it is practically impossible to work horses. The illustration at Fig. 194 shows another unusual application where the gas tractor has successfully replaced horses. The work of hauling logs over the snow covered and rough roads

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of the lumber regions is economically done by the gas traction engine and the train of wagons that it hauls. The view at Fig. 195 clearly demonstrates that a gas tractor can be operated in very deep snow, and when one considers the height of the driving wheels it will be apparent that a tractor can be used over roads that would seriously impede other forms of self-propelled vehicles.

Home-made Gas Tractors.—A discussion of gas tractor construction would not be complete without

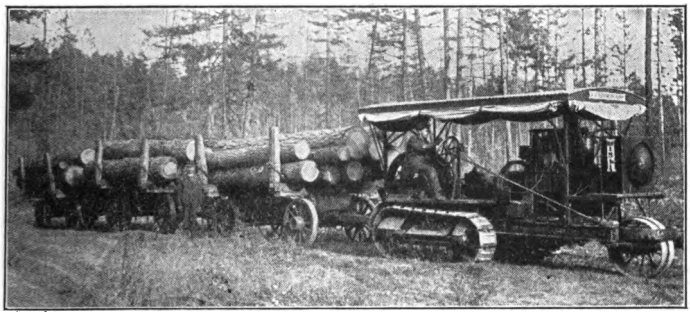

FIG. 194.—The Modern Gas Tractor Makes Hauling of Heavy Logs a Commercial Proposition.

reference to some of the ingenious outfits that have been built by farmers for their own use. The machine at Fig. 196 is a light construction in which a circular saw outfit has been made self-propelling. Only one of the rear wheels is driven, this being operated by gearing which in turn receives the power of the engine through a leather belt. Tightening this belt serves to transmit the power from the engine to the countershaft and from thence to the driven wheel. When the belt tension is released, the engine may run free of the wheel. The vehicle is directed by a steering wheel

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which operates the independently pivoted front wheels which are joined by a tiebar in just the same manner as in the Ackerman axle. The circular saw is mounted at the front end of the machine and is adapted to be driven from the engine when the tractor has reached its destination.

Another home-made tractor of substantial construction in which a single cylinder stationary type engine

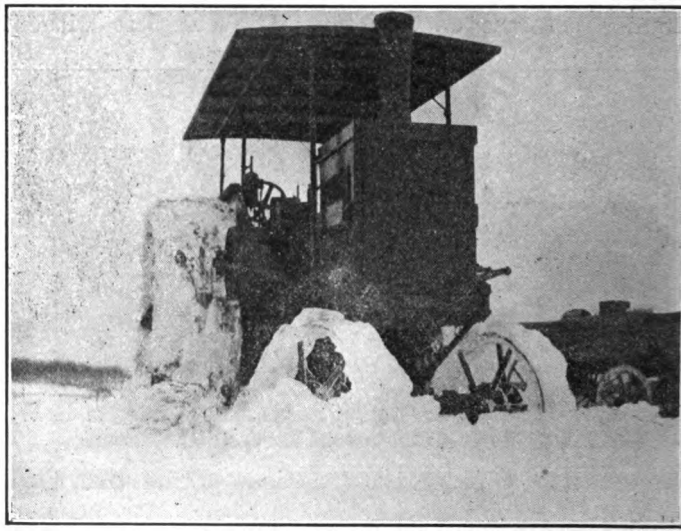

FIG. 195.—An Aultman & Taylor Tractor Operating in Deep Snow, Shows That All the Year Round Service May be Obtained From the Modern Gas Tractor.

is utilized for power, is shown at Fig. 197. The drive is by means of a belt from the engine pulley to a pulley placed on a countershaft mounted directly over the front axle. A sprocket is secured to this shaft between the two bearings, and this drives a larger sprocket

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attached to a differential gear of a cross shaft. The rear wheels are driven from this cross shaft by chain and sprocket connection. The front axle is a one-piece type and is operated by a chain steering gear and the usual form of hand wheel.

It is not considered practical for the average farmer to attempt to build a tractor, and most of the machines constructed have not been as practical as those built

FIG. 196.—Ingenious Home-made Light Tractor Saw Constructed by F. J. Jantz of Hillsboro, Kansas.

by experienced manufacturers with proper facilities. The machines illustrated are presented to show what may be accomplished by the handy man who is able to utilize odds and ends and old implement parts that ordinarily would be considered as junk and contrive a machine that is capable of doing useful work. Before the tractor had been developed to the point of per-

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fection that now obtains, many home-made machines were used for various purposes. With the advent of the improved gas tractors the farmer has been able to obtain machinery that would answer his purpose at a much lower cost than if he attempted to build a machine following his own ideas.

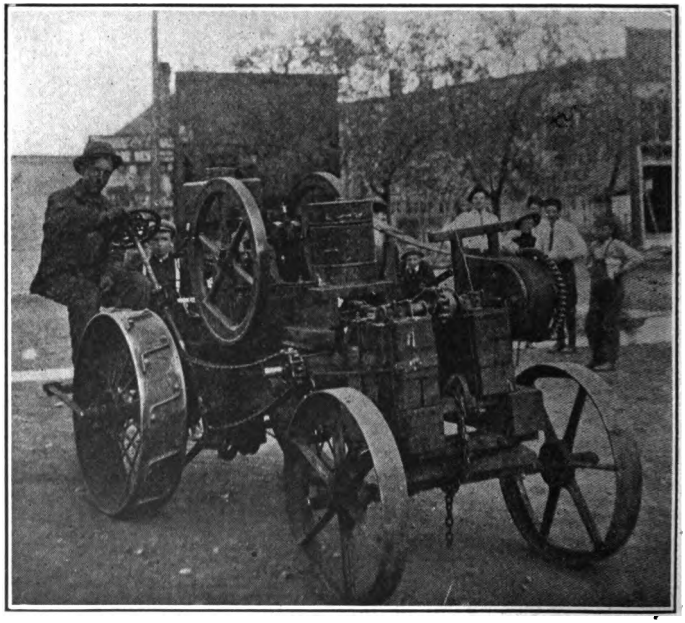

FIG. 197.—Home-made Gas Tractor Outfit Built by John H. Sands, Cavalier, North Dakota.

Auto Tractor Attachment.—The auto-tractor is an attachment of recent development, designed to be attached to the standard types of automobiles and to make it possible to use the self-propelled vehicles in performing the various kinds of farm work where mech-

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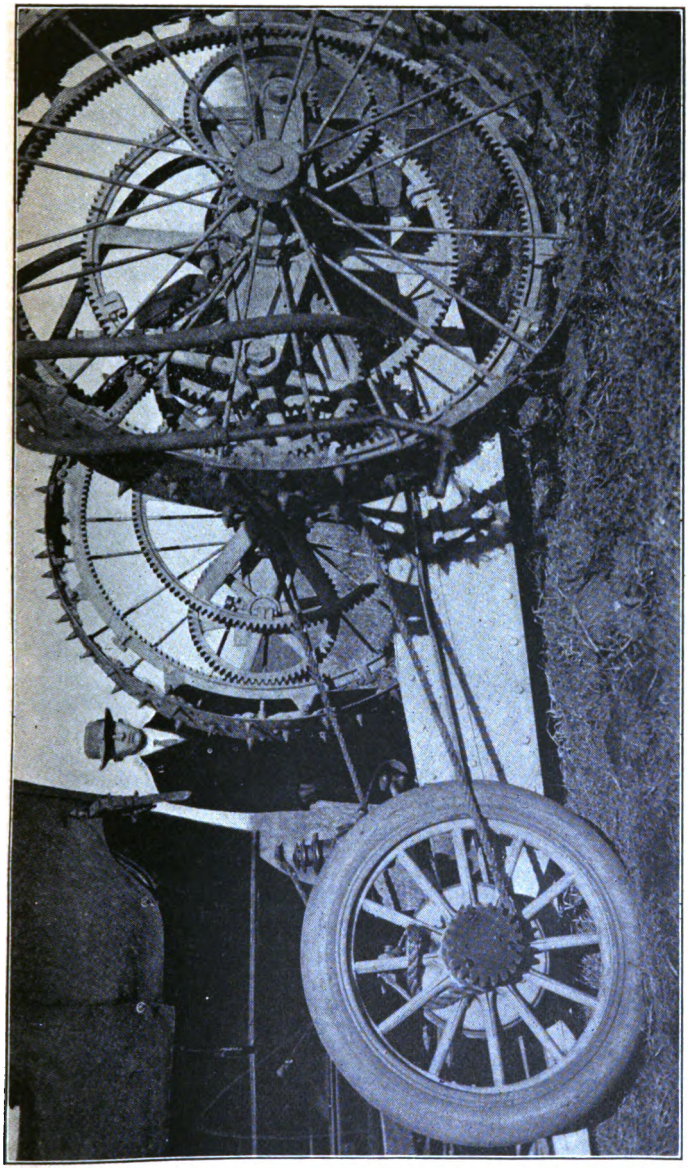

FIG. 198.—Method of Installing Auto-tractor Under Rear Axle of Car and General Construction of the Attachment Outlined.

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anical power may be utilized. The general construction may be readily determined by examining Fig. 198, which shows the tractor attachment partly in place under the auto chassis. The illustration Fig. 199 shows a side view of an automobile to which this attachment has been fitted, while that at Fig. 200 is a rear view of the same machine showing the tractor hauling a three bottom gang plough.

This device is of such form that it may be attached to any automobile of standard tread and utilizes the automobile engine and driving system which can be made to do the work of either a stationary or traction engine. The power is transmitted to the tractor attachment by means of small pinions fastened to the rear hubs of the motor car. These mesh with a train of gears which gives a speed reduction and which multiplies the available drawbar horse-power of the automobile twelvefold. The machine uses its own power to load itself in that it draws the tractor attachment into place under the car.

A pair of supporting members called "chairs" are attached to the axle which are designed to rest on the frame-members of the tractor so as to lift the wheels of the automobile from the ground.

It is claimed that from either the standpoint of initial investment or operating cost this machine is very economical. The owner of an automobile may secure many of the advantages offered by the gasoline tractor with an additional investment of about one-fourth what a gasoline tractor would cost. The tractor attachment is light in weight and the wheels, which are six feet in diameter, make it possible to operate an automobile with a tractor attachment successfully on soft or wet ground. The rear wheels of the automobile are raised clear of the ground and it is stated that when in position on the

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tractor and in operation there is less strain on the automobile than when traveling over country roads.

In operation, the automobile with tractor attachment is as easy to control as a one speed tractor because most of the driving is done entirely with the change speed lever in the high speed or direct drive position. The direct drive through the automobile gearing to the automobile rear wheels differs only in one respect from conditions present in regular road travel and that is

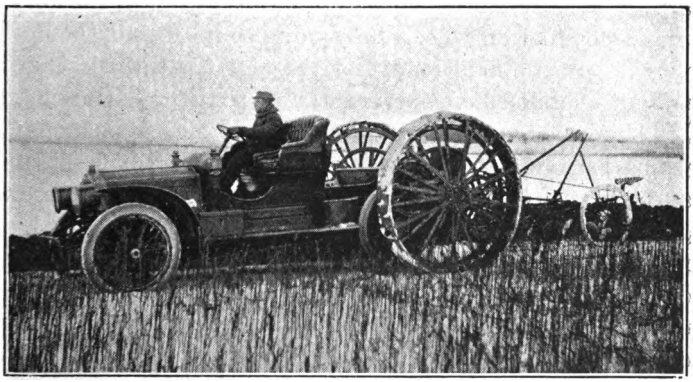

FIG. 199.—Side View of Automobile, Equipped With Auto-tractor Attachment.

that the power is applied at the face of the pinion secured to the hub instead of at the tire. The revolving rear wheels act as flywheels and make for smoother operation. The gearing is designed so that two speeds are available, one of two miles per hour and one of four miles per hour. As is true of the conventional form of tractor the lower speed is used when pulling ploughs or doing other work where the full capacity of the machine is needed. The high speed is utilized in moving wagon trains and similar road work.

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The gearing is so proportioned that when the tractor is moving at a speed of two miles per hour the automobile power plant is running at from 800 to 1000 revolutions per minute. This speed is the normal at which the average motor can operate continuously without strain and at the same time deliver practically its full horse-power. The attachment will fit automobiles ranging from twenty to ninety horse-power and as it can be attached or detached in very few minutes it does not interfere with the ordinary use of the automobile. After a day's work in the field the large traction wheels may be uncoupled and the device left in the field ready for the next day's work while the automobile conveys the workmen to their destination.

The auto-tractor is provided with a pulley attachment which permits it to be used as a stationary power plant and will operate all kinds of farm machinery from a grindstone to a threshing machine. Among some of the refinements of detail that are apparent are an auxiliary cooling system on the tractor attachment which insures that the automobile motor will not overheat on account of the low vehicle speed. A fan, pump and radiator are placed on the tractor attachment and water is passed through the auxiliary radiator as well as that of the car by means of simple connections and the motor is thus properly cooled under all conditions of weather. A storage tank holding twenty-four gallons is connected into the cooling system and an all-day run without additional water is possible.

The amount of work that can be done with the tractor attachment depends entirely upon the size of the engine in the automobile to which it is applied. The following table shows the relation between the horse-power rating of the automobile and the number of horses it will replace in field work.

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Automobile Rating.	Farm Horses Replaced.
20 Horse-power	4 to 6
30 "	6 to 9
40 "	10 to 14
50 "	14 to 18
60 "	18 to 22
75 "	22 to 30
90 "	30 to 36

As previously mentioned, the automobile is carried almost entirely by the steel frame of the tractor attachment on which the rear axle rests and which is fastened rigidly to the front axle so that the power exerted at the traction wheels is distributed evenly on the entire automobile chassis. It is claimed that the device has been examined carefully by automobile manufacturers and engineering experts and that no criticism was offered after a close study of the principles of operation had been made. It is believed that this attachment will serve to still further promote the sales of automobiles to farmers.

Future Possibilities.—The field of usefulness to which the tractor can be applied is enormous. Over ten million horses are in use in the big farming States for agricultural purposes. If the farmers of these States would replace but one out of five horses or 20 per cent, it is claimed that there is a market for over sixty thousand tractors of the medium power class, not to mention the large sale and great market for the smaller machines designed to do the work of three or four horses on the small farm.

The tractor has demonstrated its worth and is practical in construction. It has demonstrated that it will cut the cost of production of all farm products and will reduce the cost of marketing as well because the road to market is shortened by mechanical power.

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FIG. 200.—Rear View of Automobile With Auto-tractor Attachment, Showing Practical Application in Ploughing.

One authority says, "The tractor is at the dawn rather than at the twilight of its development." It has developed from a monstrous, inefficient toy into a powerful and efficient servant.

It is not only on the farm that the tractor can be

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used to advantage. In contracting and construction work its uses are unlimited. Many deposits of stone have been converted into surfacing material for highways by its aid. It has been used in building and maintaining roads, in digging irrigation canals, and filling drainage ditches. It has hauled machinery to the mines, brought the ore to the surface and carried it to the railroad or smelting plant. Enormous logs have been taken from forests where big teams of horses could not be handled. It has been used even in the field of modern amusement enterprises, and a number of the big tent shows are shifting their heavy trucks with a traction engine which also runs a dynamo and furnishes power for electrically lighting the tents during the evening exhibition.

The performance of the tractor in the past is but a promise of what it may accomplish in the future. Much depends on the education of the farmer. It is not natural to assume that one who has been familiar with horses since childhood will be ready to replace these with mechanical power about which he knows comparatively nothing. As the tendency of modern farming is to make it more scientific and an engineering proposition, the farmer of the future will be trained in solving mechanical problems. While it is to the younger element that we must look for substantial progress and ready adoption of new methods, much will be accomplished by even the conservative old-time farmer who will realize the advantages of mechanical traction, study the applications and forms of gas tractors best suited to his work and link the invaluable experience of the past with the progressive ideas of the future.

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CHAPTER XI.

TRACTOR DESIGNS FOR 1917.

Trend of Design—Requirements of All-purpose Tractor—Three-wheel Tractors—Tractor that Acts as Horse—Two-cycle Oil Engine Used—Motor Cultivator—A Garden Tractor—Dust Separator—Anti-friction Bearings for Tractors—Specifications of Late Tractor Designs.

Trend of Design.—The most prominent feature noted in late tractor designs is the endeavor of builders to have light and strong tractors better adapted to general work on small and medium-sized farms than the earlier heavy designs. The trend is unmistakably toward the small and medium-weight machine, just as the trend in automobile designing is toward the medium-weight cars of moderate price. Tractor prices have been reduced and their use is increasing in all sections of the country. Before describing the improvements in light-tractor design it may be well to recapitulate briefly the requirements of the ideal, all-purpose tractor:

First, it should be universally adaptable, so that it can do all kinds of belt or drawbar work. It should be just as well adapted for running farm machines requiring power as it is for hauling ploughs, harrows or loaded wagons.

Second, the ratio between power and weight and the arrangement of components are important things to consider. If the tractor is too light it will not have the required traction effort between the drive wheels and the ground, and considerable useful power will be

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dissipated in slippage. On the other hand, if the machine weighs too much it will pack the soil and will not be practical for use on soft ground.

Third, as much contact area as possible between the traction members and the ground should be provided in order to avoid loss of power through slipping and packing of the soil due to concentration of much weight on a limited bearing area.

Fourth, it is desirable that the engine be capable of operating on the cheaper liquid fuels such as kerosene, distillate and others of the more plentiful products of petroleum. The rapidly increasing cost of gasoline makes it imperative to use other fuels and as the tractor engines, for the most part, are heavy-duty constant-speed types, no difficulty should be experienced in using kerosene.

Fifth, the tractor should be designed with special reference to the work it is to do and should be constructed of sufficiently good materials so that the weight may be kept within reasonable limits and combine strength with lightness. The tractor should be easy to start and the various controlling functions such as gear shifting, clutch operation and steering should be simplified and control levers so proportioned as to be handled without requiring great muscular exertion. It is evident that the simple tractor will be easier to understand, maintain, and repair. In fact, the simpler designs will be more easily operated by the average farm hand. The construction should be so arranged that automatic steering can be secured when doing certain classes of work, such as ploughing, so that the engineer or operator may utilize part of the time in handling the ploughshares.

Quite a number of the tractors of modern design

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answer nearly all of the above requirements. The mechanism is simple and the relation of the parts is good from both theoretical and practical considerations. It is a safe statement that the tractors which more nearly incorporate the ideal requirements enumerated are those which follow the rules of practice established by automobile builders. In essential elements the automobile and gas tractor are similar, though, of course, the parts and detail arrangement must be modified for the heavier and slower machines. One of the marked tendencies in tractor design is to use multiple-cylinder power plants.

When the gasoline tractor was first evolved a large horizontal single-cylinder stationary engine was mounted on the supporting frame or chassis that was the same as those used on steam tractors. At the present time multiple-cylinder engines are used because these have less vibration and the general arrangement of the chassis parts have been altered to some extent. In the steam tractor the drive gearing was generally exposed and was composed of a gear train of heavy cast-iron gears with practically no finish. At the present time not only the gearing, but other parts of the transmission system, such as the clutch, are encased and protected from grit and dirt. Cut alloy steel gears running in oil and operated in practically the same way as change-speed gearing on automobiles have replaced the heavier forms used on the early machines. Pressed steel and standard structural forms such as channels and I-beams are replacing the cumbersome cast frames of the early tractor. Whereas the earlier machines used plain bearings at all parts, the modern tractors use ball and roller bearings, which not only have longer life than the plain babbitted type, but which offer a material saving in

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power, as well as reducing the repair expense by keeping the parts in the proper relation longer. While it would take at least half a day for an experienced man to pour a babbitt bearing and fit it properly, the anti-friction bearings, which are interchangeable, can be easily removed and replaced by new ones in much less time.

Three-wheel Tractors.—Considerable interest is being displayed in the three-wheel constructions. In

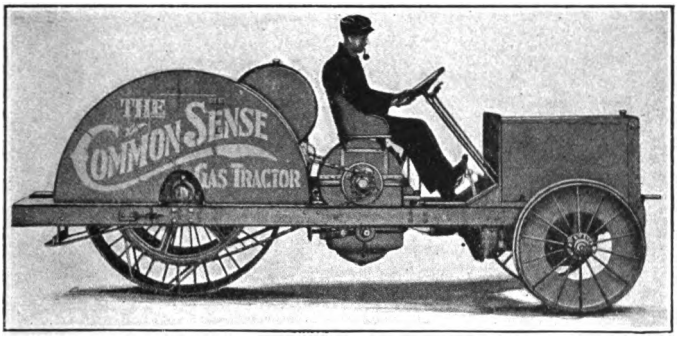

FIG. 201.—The Common Sense Gas Tractor is Built Very Much on the Lines of an Automobile.

fact most of the light tractors that are being offered this year are of the type having a single traction member and two steering wheels. The type shown at Fig. 201 is one of recent construction and may be considered fairly representative of this class. The front wheels are 36 inches in diameter with a 6-inch face, while the main drive wheel is 62 inches in diameter with a 24-inch face. The engine is a four-cylinder, four-cycle motor, capable of delivering 25 horse-power belt pull and 15 horse-power drawbar pull at approximately 900 revolutions. The cooling system includes a flat tube radiator through which water is circulated by a 6½-inch centrifugal pump.

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Ignition is by magneto. The transmission provides two speeds ahead and one reverse. The low speed is $1\frac{3}{4}$ miles per hour—the high speed, $2\frac{1}{2}$ miles per hour. Larger sprockets are furnished which may be easily fitted and which will give higher speed.

This tractor will pull two gang ploughs or two disk harrows. It is capable of hauling two binders or two drills and will trail 3 to 5 grain wagons. It will pull

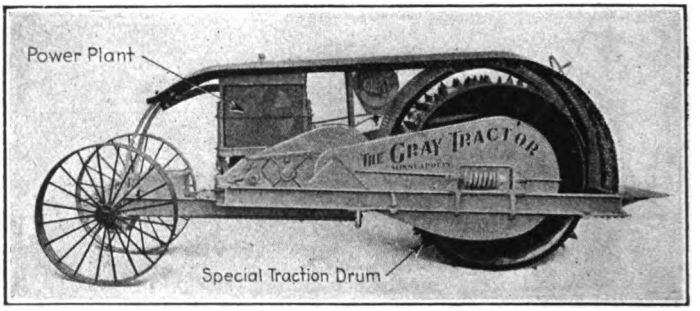

FIG. 202.—The Gray Tractor Utilizes Special Drum Traction Member.

two manure spreaders or an 8-foot road grader. It has sufficient belt power to operate a 32-inch separator, a silage cutter, corn shredder, corn sheller, circular saw, feed grinder, water, pump, hay baler or grain elevator. The machine is easily controlled, as it is handled very much as an automobile. Especial attention is directed to the thorough inclosure of all gearing in dust-proof, oil-tight cases.

The machine shown at Fig. 202 is practically a three-wheel type, though the drive is through an extremely wide traction member or drum as outlined at Fig. 203. This not only provides good traction, but carries the

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weight on a great area. It is said that this tractor can turn in a 22-foot circle and that the machine can be maneuvered equally as well on ploughed land as on hard ground. One advantage of the three-wheel forms described is that the mechanism is simplified, owing to the elimination of the differential. The power plant is a four-cylinder, four-cycle auto-type engine. Owing to the compactness of the machine, it is specially adapted for orchard cultivation. In all features except the wide-drive drum this tractor follows conventional practice.

Tractor Acts as Horse.—The tractor shown at Fig. 204 is distinctive in construction, inasmuch as it is a practical motor-driven machine that can be hitched to any horse-drawn implement and operated from the seat of the vehicle the tractor is drawing, just as though it was being drawn by horses. This is an advantage, because it can be used in connection with the horse-drawn implements already in the farmer's possession. The tractor is controlled by means of three wheels and a lever on the end of a long column which consists of three lengths of tubing, one inside of the other. This control column is connected with the tractor through a universal joint and can be swung at will to any position desired. The middle wheel is the steering, the small wheel in front of the steering wheel operates the clutch and the remaining wheel actuates the gear-shifting apparatus. The carbureter control which is used to regulate the engine speed is in the form of a lever projecting in front of the clutch control wheel. The motor gives 30 horse-power on the belt. It is a four-cylinder, four-cycle, heavy-duty type following approved automobile practice.

The distinctive feature is the traction member or "crawler," as it is called, which consists of an endless

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chain apron of metal plates, each link of which is a single piece of metal connected to the adjoining piece by means

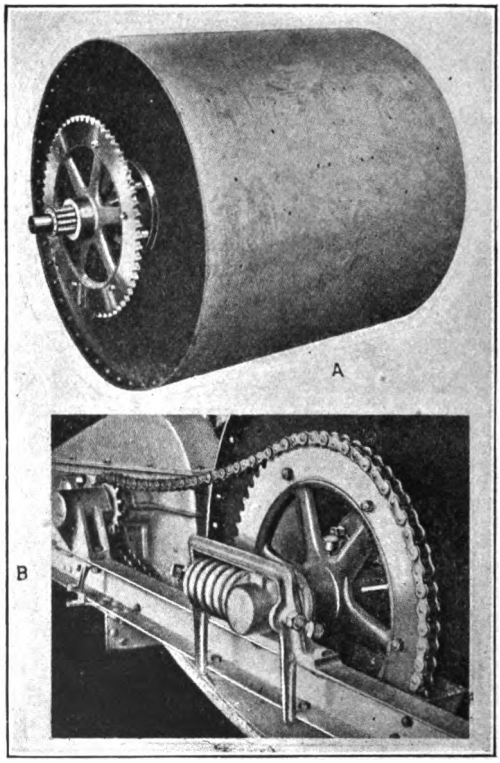

FIG. 203.—Traction Drum of Gray Tractor at *A* and Method of Absorbing Chain Drive Shocks by Coil Buffer Spring Shown at *B*.

of a connecting pin having a large bearing surface. Either malleable iron or vanadium steel links may be furnished. The endless chain is driven by a manganese

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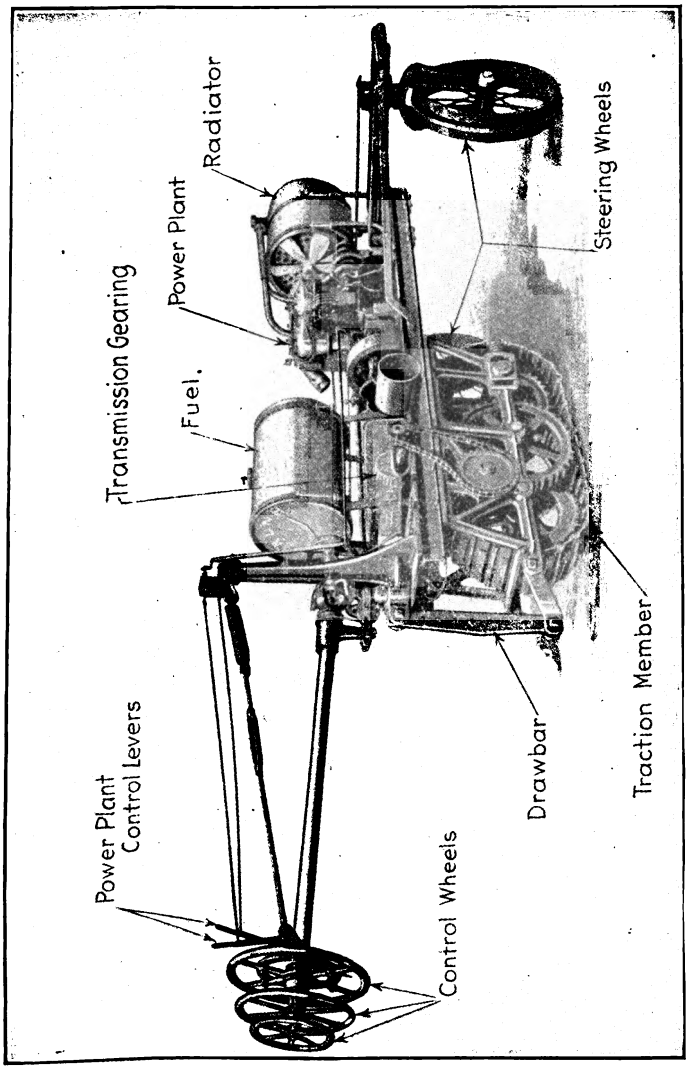

FIG. 204.—The Bates Steel Mule Tractor is Attached to all Farming Implements Just as Animals are and is Really a Mechanical Horse. This is a Distinctive Design.

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steel gear located at the rear of the traction tread member, while the centre part is supported by two flanged idler wheels which prevent the tread from slipping sideways and at the same time guide it properly. The advantages of the track-laying type of drive, where the machine is to be used in soft ground, are now well recognized, as the weight of the machine is distributed over so large a

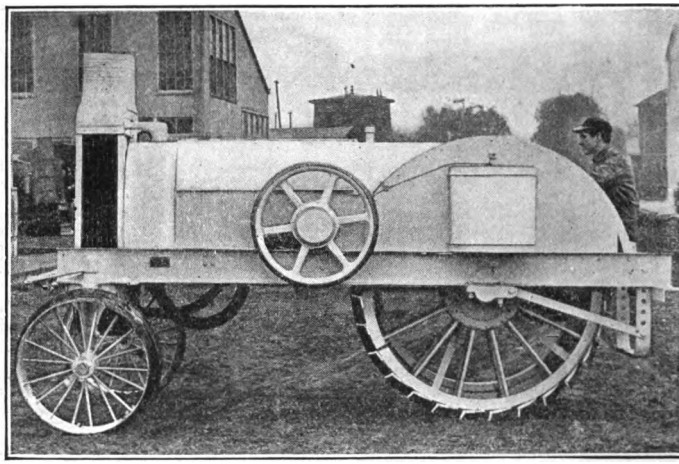

FIG. 205.—Hart-Parr "Little Devil" Tractor is a Typical Medium Weight. Three-wheel Type.

surface that it will not sink even into soft ground. The ground pressure is lighter than that of a man. The area to support the weight is so large that a horse would need shoes having an area of 1 square foot each attached to its four feet to enable it to tread as lightly on the ground. The turning radius is $8\frac{3}{4}$ feet, so the machine will turn in an 18-foot circle. The width of the front tread is adjustable from 3 feet $9\frac{1}{4}$ inches to 6 feet

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9¾ inches, which allows of cultivating rows 30 to 48 inches wide.

Two-cycle Engine Used.—The type of light tractor shown at Fig. 205 is equipped with a double-cylinder

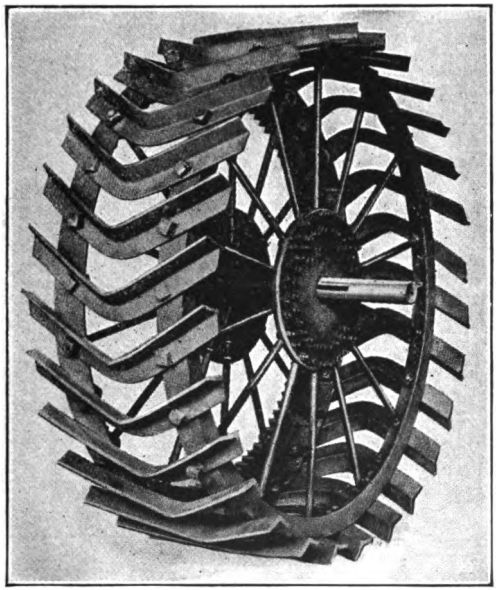

FIG. 206.—Skeleton Type of Drive Wheel Used on Hart-Parr "Little Devil" Oil Tractor.

engine of the two-cycle type which is attached to the frame by a three-point suspension. The cylinders are of 5½ inch bore and 7-inch stroke, and the engine is rated as 22 brake horse-power in belt and 15 drawbar horse-power. Heavy-duty ball bearings are used at all points except the engine and rear axle bearings. This engine has been designed to use kerosene or other low-

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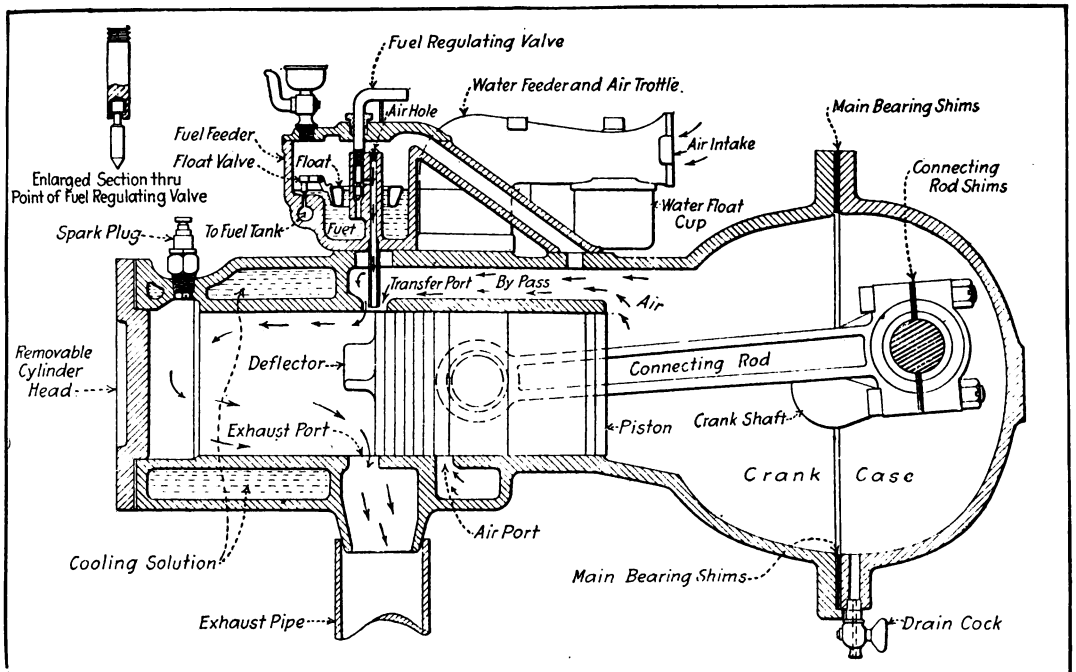

FIG. 207.—Sectional View of Two-stroke Cycle Oil Engine Used on Hart-Parr Three-wheel Tractor, Showing Method of Fuel Supply.

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grade fuels after an initial start is obtained on gasoline. Oil is used for cooling the engine, this providing a non-freezing medium that will not deposit scale in the radiator or rust the metal parts. A tractor of this kind can do the work of eight big, strong horses. It can be used for all forms of belt work and will pull all types of horse-

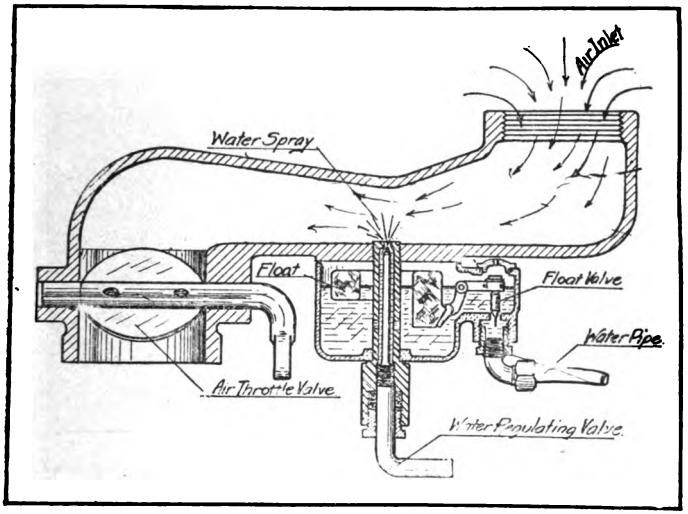

FIG. 208.—Sectional View of Water Spray Portion of Hart-Parr Oil Engine Carburetor

drawn implements. It has a capacity for drawing three 14-inch plows under average conditions. It is a very simple machine and easily operated, as it steers just like an automobile when not following a furrow and is self-steering when ploughing. The machine weighs 6,000 pounds. A sectional view of the engine, showing its simplicity and details of the fuel-feeding device is given at Fig. 207. The arrangement of the water feed can

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be readily ascertained by reference to Fig. 208. Both fuel and water feed may be regulated to secure proper mixture proportions.

Motor Cultivator.—The motor cultivator shown at Fig. 209 is a form of tractor, though, of course, it is not adapted for heavy work. It is designed so that it can be hitched up to a mowing machine, hay rake, or harrow

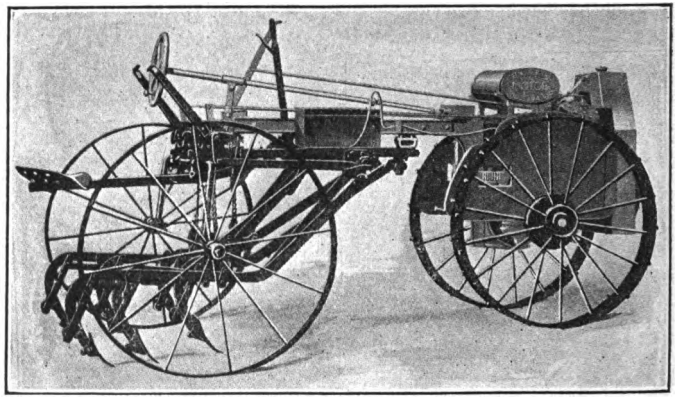

FIG. 209.—The Universal Motor Cultivator with One of the Many Possible Attachments that can be Used with It.

just as well as to the cultivator attachment. The power plant is a two-cylinder, V-type motor, of 3½-inch bore, and 5-inch stroke. The transmission is through worm gearing, housed in a dust-proof oil-retaining case. The gearing is supported by ball bearings. The tractor attachment is supported by the two driving wheels which are 40 inches in diameter and 5 inches face. Cleats are provided on the wheels to obtain greater traction. The machine weighs but 1,000 pounds and is easily handled by the 12-brake horse-power motor which has a draw-

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bar pull about equal to an ordinary team of horses. The machine may be driven at any speed desired up to 4 miles per hour and is easily guided from the driver's seat on the trailing vehicle. A special wheeled trailer is provided to carry the driver when operating machines that have no seat and for driving the tractor from place to place without transporting the implements.

A Garden Tractor.—The Beeman garden tractor and "walking" engine shown at Fig. 210 is without doubt

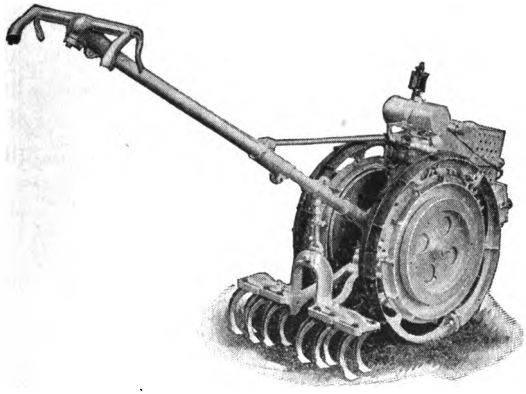

FIG. 210.—The Beeman Garden Tractor and Walking Engine is Ideal for Small Farms.

the smallest machine of this class, and is intended for the lighter classes of field work. It can also be used as a portable or rather self-moving power plant for use in garden, house, barn, or yard. It is especially valuable for cultivating all kinds of garden truck. It cultivates any crop now cultivated by hand, hand-wheel or one-horse cultivator, and all forms of hoes, weeders, cultivator teeth, knives, discs, etc., used with the hand-wheel cultivator can be attached to this machine. The

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operator walks and steers like he does a lawn mower, but without the work. He always has perfect control, as there are only two levers to operate—the one on the right handle controls the speed and the one on the left controls the clutch. The speed is always under control and the height of the handles easily adjusted to suit the operator. The machine is quickly set to cultivate any depth desired by regulating the height of two free-swung wheels or shoes which ride between the operator and the cultivator frame. The frame bearing the attachments, hoes, knives, discs, etc., is under complete control of the operator all the time through the steering handle independently of the position of the wheels in front, and without affecting the steering control of them. The main specifications of this interesting appliance follow: Engine—$3\frac{1}{2}\times4\frac{1}{2}$ four-cycle. Four horse-power on the belt, $1\frac{1}{2}$ horse-power on the drawbar. Speed—230 to 2,200 R.P.M. Travels 1 to 3 miles per hour on the road and $\frac{3}{4}$ to $2\frac{1}{2}$ in field work. Cooling system—Thermosyphon system with comb radiator and fan. Ignition—Standard magnetos, no batteries. Oiling system—Splash and gravity. Carbureter—Standard make. Wheels—Height, 25 inches. Width, over all, 17 inches. Tread, $3\frac{1}{2}$ inches. Weight—About 450 pounds, made specially heavy to insure traction. One gallon of gasoline will run the machine about five hours under work in the field and for about seven hours on the belt.

Dust Separator.—One of the most useful of tractor accessories is shown at Fig. 211. This is a simple device intended to filter the air entering the carburetor. It consists of a large container having an ingenious internal arrangement of baffle plates to collect dust. The air enters the sides of the container, the dirt is deflected to the bottom, from which it may be drawn by removing

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a screw cap and the clear air passes out of the top of the device to the air intake of the carburetor.

Every experienced tractor operator knows the effects of dust and sand on the operation and life of a tractor in field. It wears the pistons and piston rings, scores the cylinders, pits the valves, and cuts out bearings, and

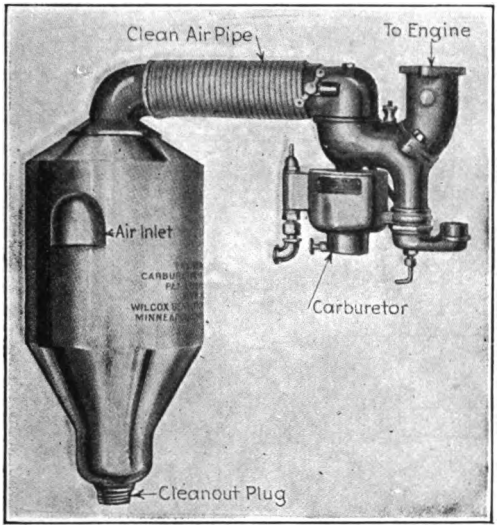

FIG. 211.—The Bennett Dust Filter for Removing Grit from Air Drawn in the Engine through the Carburetor.

in fact is the most important cause of large repair bills. In some parts of the country the dust is so heavy at all times as to choke up the lubricating oil in less than a day's run, so that it has to be drained off and replenished to prevent overheating and wear on the motor. The Bennett air cleaner does away with all these troubles and expenses by removing all the dust and sand from the

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air before it enters the carburetor. This not only saves the motor, but lengthens the life of the carburetor, which is often the cause of considerable repair expense through the wear on its parts due to dust.

Anti-friction Bearings for Tractors.—An instance of the refinement tractor design is undergoing is the

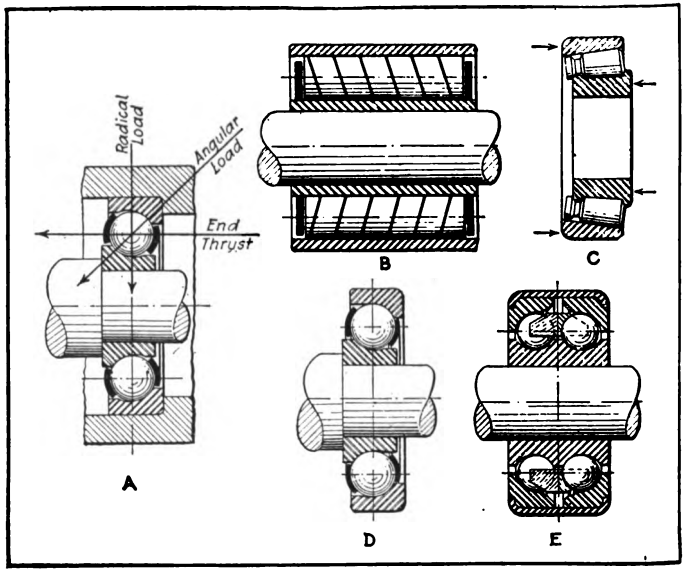

FIG. 212.—Types of Anti-friction Bearings that are Meeting Favor of Tractor Designers.

increasing application of ball and roll bearings to the mechanism. The leading forms of anti-friction bearings are outlined at Fig. 212. Before describing the bearing types, it will be well to consider the loads bearings may be subjected to. Bearings of all types are subject to three main loads as clearly outlined at Fig. 212*A*. These

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in order of their importance are radial load, angular load, and end thrust. A radial load is one that is exerted in a straight, vertical line at right angles to the horizontal center line of the shaft. An angular load is one composed of radial and end thrust components and is applied at an angle instead of radially or parallel to the shaft axle. Any force applied in a direction parallel to the shaft axis is termed "end thrust."

All anti-friction bearings consist of inner and outer steel rings with a series of balls or rollers between them. The rings are used to protect the shaft and bearing box from wear. The type of bearing at Fig. 212*B* is a very popular form in which flexible steel rollers are used to carry the load. This type is adapted only for radial loads. The taper roller bearing at *C* can withstand an angular load or a combined radial and thrust pressure. The rolls are solid and are shorter than the flexible rollers because they are stronger. The hollow flexible roller has the marked advantage of distributing lubricant and holding a quantity of oil or grease in its interior. When assembled in bearings, one set of rollers is wound right-hand, the other series has a left-hand groove. This keeps the oil moving from one side of the bearing to the other. When flexible roller bearings are used at points having angular or thrust loads, a ball bearing of the thrust washer form must be employed in connection with it. Under these conditions the taper roller bearing can be used alone. The cup and cone type of ball bearing at *D* is capable of resisting an angular load, a one-direction thrust, or a radial load. Single-row ball bearings of similar design except that they have a vertical load-line instead of an angular one, are better adapted to resist purely radial loads. The double-row bearing at *E* is a unit form that can resist loads from

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any direction with equal efficiency. It resists end thrust and radial loads in combination and is well adapted for heavy-duty service.

Specifications of Late Tractor Designs.—The student and practical agriculturist cannot fail to be interested in the compilation of the features of typical light tractor designs that follows. This gives the information desired in a direct way that permits of ready comparison. These are representative designs that are actively marketed for the 1916–17 season and as each form is illustrated, the features of construction peculiar to individual machines may be noted.

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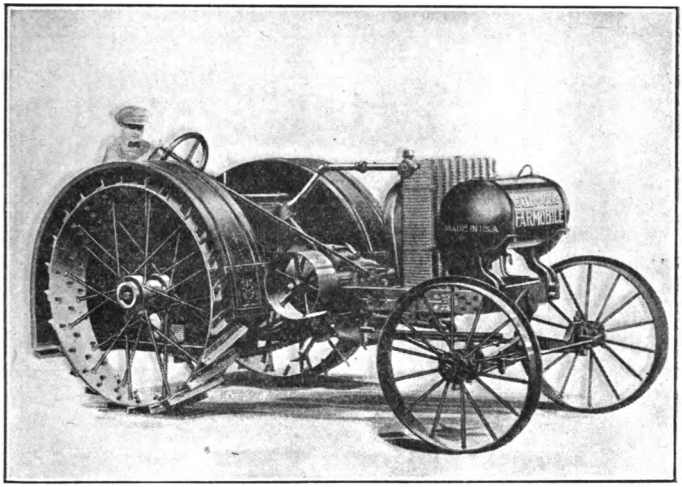

FIG. 213.—Galloway's "Farmobile."

SPECIFICATIONS.

Rated Tractive H.P., 12.
Rated Belt H.P., 20.
No. of Cylinders, 4.
Cylinder Bore, 4½ Inches.
Piston Stroke, 5 Inches.
Ignition, High-tension Magneto.
Governor, Throttling.
Clutch, Raybestos Faced Cone.
Cooling, Water.
Carburetor, Gasoline.
Water Capacity, 14 Gallons.
Fuel-tank Capacity, 25 Gallons.
No. of Speeds, 2.
Low Speed, 1.66 Miles per Hour.
High Speed, 2.32 Miles per Hour.
Belt Pulley Diameter, 12½ Ins.
Belt Pulley Width, 7 Inches.
Bearings, Roller and Ball.
Thrust Washers.
Drive Wheel Diameter, 5 Feet.
Drive Wheel Width, 24 Inches.
Front Wheel Diameter, 40 Ins.
Front Wheel Width, 10 Inches.
Wheel Base, 7 Feet 9 Inches.
Width of Machine, 8 Feet.
Length of Machine, 15 Feet.
Height of Machine, 6 Feet.
R.P.M. Engine Shaft, 800 Normal.
Shipping Weight, 5450 Pounds.
Circle, Machine can Turn in 17 Feet Radius.

Remarks: Draw Bar Pull 2000 Pounds on High Speed.

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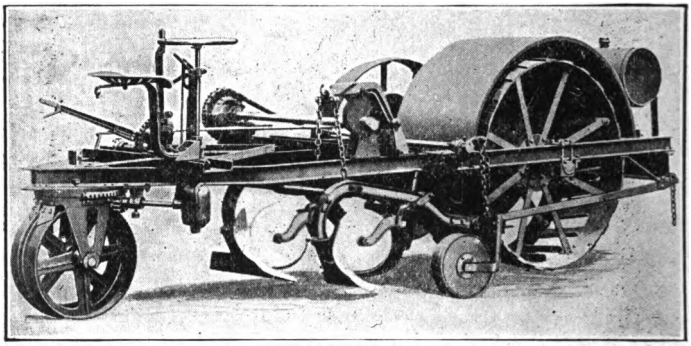

FIG. 214.—Rumley "All Purpose" Tractor.

SPECIFICATIONS.

Rated Tractive H.P., 8.
Rated Belt H.P., 16.
No. of Cylinders, 4.
Cylinder Bore, 4 Inches.
Piston Stroke, 5½ Inches.
Ignition, Dry Cells and Magneto.
Governor, Ball and Spring Type, Throttling.
Clutch, Three-disc.
Cooling, Water, Honeycomb Radiator.
Carburetor, Gasoline.
Water Capacity.
Fuel-tank Capacity.
No. of Speeds, 1 forward and Reverse.
Low Speed.
High Speed, 2.1 Miles per Hour.
Belt Pulley Diameter, 14 Inches.
Belt Pulley Width, 6½ Inches.
Bearings, Roller.
Drive Wheel Diameter, 54 Ins.
Drive Wheel Width, 26 Inches.
Front Wheel Diameter, 26 Ins.
Front Wheel Width, 5¼ Inches.
Wheel Base.
Width of Machine, 6 Feet 7 Inches.
Length of Machine, 16 Feet 6½ Inches.
Height of Machine, 5 Feet 2 Inches.
R.P.M. Engine Shaft, 850.
Shipping Weight.
Circle Machine can Turn in

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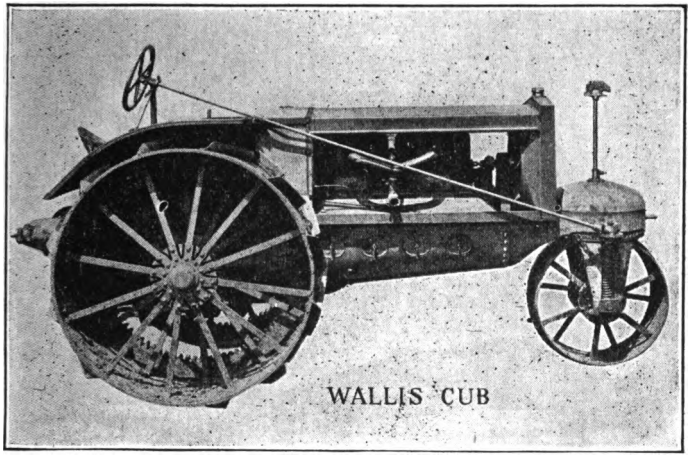

FIG. 215.—Wallis Cub Tractor.

SPECIFICATIONS.

Rated Tractive H.P., 4000 Lbs. D. B. Pull.
Rated Belt H.P., 50.
No. of Cylinders, 4.
Cylinder Bore, 6 Inches.
Piston Stroke, 7 Inches.
Ignition, Magneto.
Governor, Throttling.
Clutch,
Cooling, Water.
Carburetor, Gasoline.
Water Capacity,
Fuel-tank Capacity,
No. of Speeds, 2 Forward.
Low Speed, 2¼ Miles per Hour.
High Speed, 3 Miles per Hour.
Belt Pulley Diameter,
Belt Pulley, Width,
Bearings, Roller.
Drive Wheel Diameter, 60 Ins.
Drive Wheel Width, 20 Inches.
Front Wheel Diameter, 34 Ins.
Front Wheel Width, 14 Inches.
Wheel Base,
Width of Machine,
Length of Machine,
Height of Machine,
R.P.M. Engine Shaft,
Shipping Weight, 8500 Pounds.
Circle Machine can Turn in

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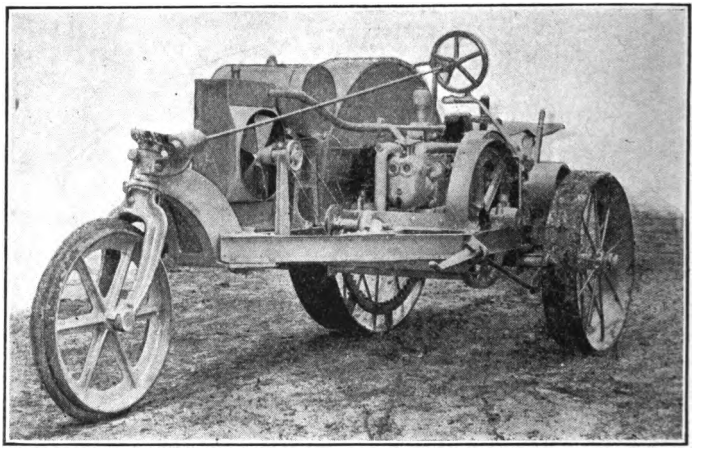

FIG. 216.—Big Bull Tractor.

SPECIFICATIONS.

Rated Tractive H.P., 7.
Rated Belt H.P., 20.
No. of Cylinders, 2 Cylinders Opposed.
Cylinder Bore, 5¼ Inches.
Piston Stroke, 7 Inches.
Ignition, Magneto, Impulse Starter.
Governor, Flyball Type, Throttling.
Clutch, External Contracting.
Cooling, Water, Forced Circulation.
Carburetor, Gasoline or Kerosene.
Water Capacity,
Fuel-tank Capacity,
No. of Speeds,
Low Speed,
High Speed, 2½ Miles per Hour.
Belt Pulley Diameter,
Belt Pulley Width,
Bearings, Roller in Drive Wheel, Bronze-back, Babbitt Elsewhere.
Drive Wheel Diameter, 60 Ins.
Drive Wheel Width, 14 Inches.
Front Wheel Diameter, 32 Ins.
Front Wheel Width, 6 Inches.
Wheel Base,
Width of Machine,
Length of Machine,
Height of Machine,
R.P.M. Engine Shaft, 650–720.
Shipping Weight, 4500 Pounds.
Circle Machine can Turn in

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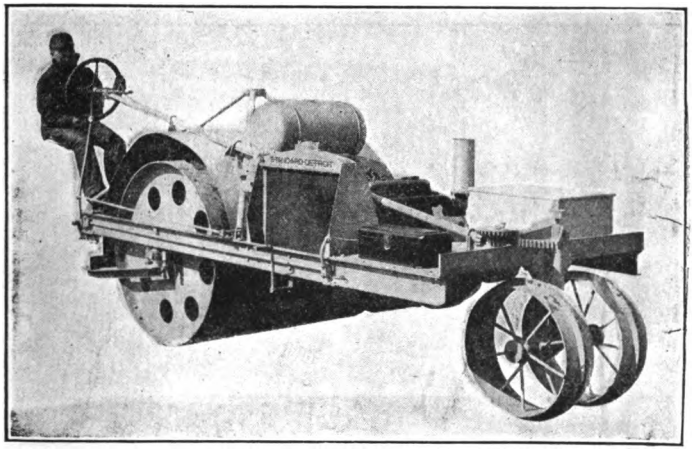

FIG. 217.—Standard Detroit.

SPECIFICATIONS.

Rated Tractive H.P., 10-2200 Pounds D. B.
Rated Belt H.P., 30.
No. of Cylinders, 4.
Cylinder Bore, 3¾ Inches.
Piston Stroke, 4 Inches.
Ignition, Magneto.
Governor, Throttling.
Clutch,
Cooling, Water, Tubular Radiator.
Carburetor, Gasoline.
Water Capacity,
Fuel-tank Capacity,
No. of Speeds,
Low Speed,
High Speed, 2 to 3 Miles per Hour.
Belt Pulley Diameter,
Belt Pulley Width,
Bearings,
Drive Wheel Diameter, 44 Ins.
Drive Wheel Width, 24 Inches.
Front Wheel Diameter, 24 Ins.
Front Wheel Width, 8 Inches.
Wheel Base,
Width of Machine,
Length of Machine,
Height of Machine,
R.P.M. Engine Shaft,
Shipping Weight, 3945.
Circle Machine can Turn in

Remarks: Double Drum Traction Member.

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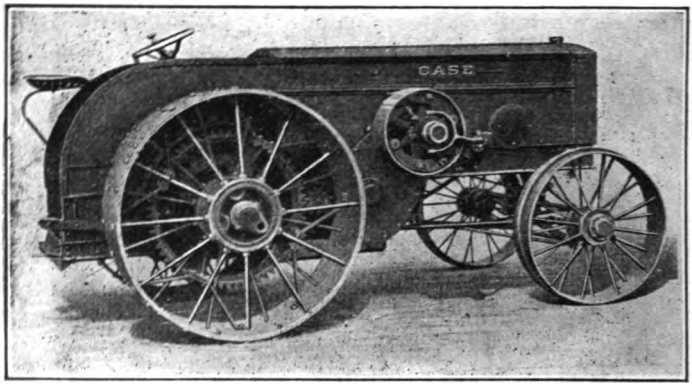

FIG. 219.—Case "25" Tractor.

SPECIFICATIONS

Rated Tractive H.P., 12 to 15.
Rated Belt H.P., 24.
No. of Cylinders, 2 Cylinders Opposed.
Cylinder Bore, 7 Inches.
Piston Stroke, 7 Inches.
Ignition, High Tension Magneto.
Governor, Throttling Flyball.
Clutch, Asbestos Faced Internal Shoes.
Cooling, Thermo-Syphon, Water.
Carburetor, Gasoline.
Water Capacity, 9 Gallons.
Fuel-tank Capacity, 17 Gallons.
No. of Speeds, 2 Forward, 1 Reverse.
Low Speed, 1.75 Miles per Hour.
High Speed, 2.2 Miles per Hour.
Belt Pulley Diameter, 22 Inches.
Belt Pulley Width, 7½ Inches.
Bearings, Roller,
Drive Wheel Diameter, 56 Ins.
Drive Wheel Width, 18 Inches.
Front Wheel Diameter, 38 Ins.
Front Wheel Width, 8 Inches.
Wheel Base, 7 Feet 6 Inches.
Width of Machine, 6 Feet.
Length of Machine, 12 Ft. 5 Ins
Height of Machine, 6 Feet.
R.P.M. Engine Shaft, 600.
Shipping Weight, 9000 Pounds.
Circle Machine can Turn in

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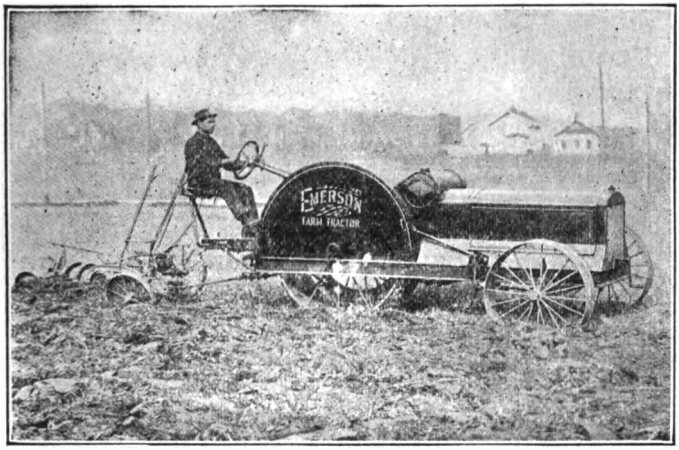

FIG. 220.—Emerson Farm Tractor.

SPECIFICATIONS.

Rated Tractive H.P., 12.
Rated Belt H.P., 20.
No. of Cylinders, 4.
Cylinder Bore, 4½ Inches.
Piston Stroke, 5 Inches.
Ignition, Magneto.
Governor, Throttling.
Clutch,
Cooling, Water.
Carburetor,
Water Capacity,
Fuel-tank Capacity,
No. of Speeds, 2 Forward, 1 Reverse.
Low Speed, 1.6 Miles per Hour.
High Speed, 2.3 Miles per Hour.
Belt Pulley Diameter,
Belt Pulley Width,
Bearings, Roller.
Drive Wheel Diameter, 60 Ins.
Drive Wheel Width, 24 Inches.
Front Wheel Diameter, 36 Ins.
Front Wheel Width, 10 Inches.
Wheel Base,
Width of Machine,
Length of Machine,
Height of Machine,
R.P.M. Engine Shaft,
Shipping Weight, 5100 Pounds.
Circle Machine can Turn in

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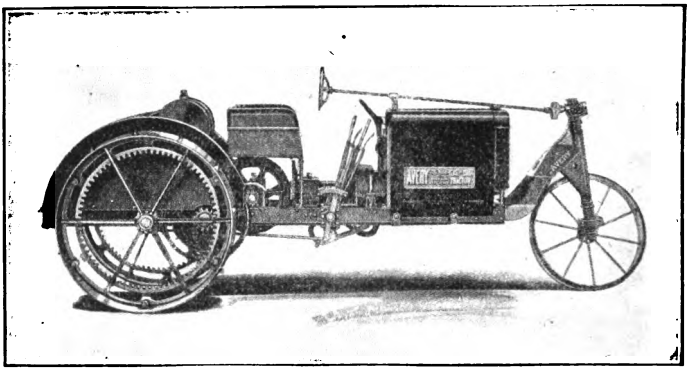

FIG. 221.—Avery 5–10 Tractor.

SPECIFICATIONS.

Rated Tractive H.P., 5.
Rated Belt H.P., 10.
No. of Cylinders, 4.
Cylinder Bore, 3 Inches.
Piston Stroke, 4 Inches.
Ignition, Magneto.
Governor, Throttling.
Clutch, Friction Disc.
Cooling, Water.
Carburetor, Gasoline.
Water Capacity,
Fuel-tank Capacity,
No. of Speeds, 3 Forward and Reverse.
Low Speed, 1½ Miles per Hour.
High Speed, 3½ Miles per Hour.
Belt Pulley Diameter,
Belt Pulley Width,
Bearings, Roller in Transmission, Plain in Wheels,
Drive Wheel Diameter, 38 Ins.
Drive Wheel Width, 5 Inches.
Front Wheel Diameter, 28 Ins.
Front Wheel Width, 5 Inches.
Wheel Base,
Width of Machine,
Length of Machine,
Height of Machine,
R.P.M. Engine Shaft,
Shipping Weight, 1700 Pounds.
Circle Machine can Turn in

Remarks: Intermediate or Plowing Speed, 2 Miles per Hour.

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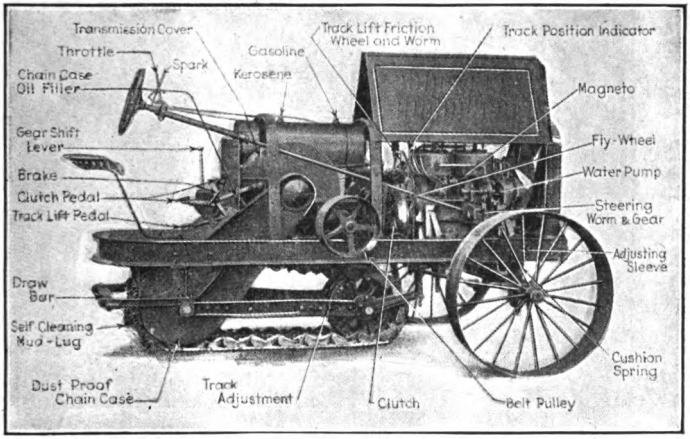

FIG. 223.—Side View of Tom Thumb Tractor with Hood Sides Removed to Show Arrangement of Power Plant Parts and Other Mechanism.

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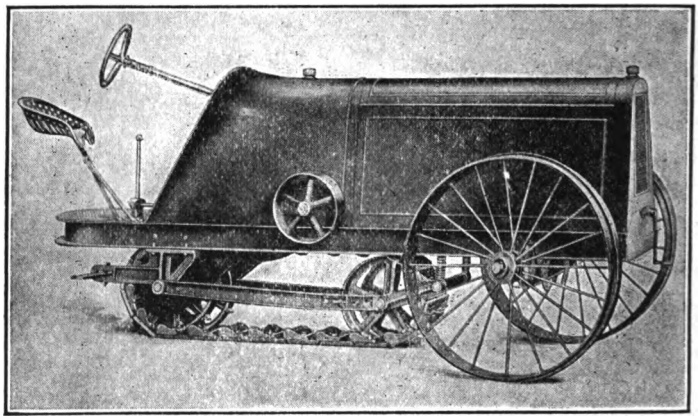

FIG. 224.—Tom Thumb Tractor.

SPECIFICATIONS.

Rated Tractive H.P., 12.
Rated Belt H.P., 20.
No. of Cylinders, 4.
Cylinder Bore, 4 Inches.
Piston Stroke, 6 Inches.
Ignition, High Tension, Impulse Starter.
Governor, Throttling.
Clutch, Special Traction Lift.
Cooling, Water, Honeycomb Radiator.
Carburetor, Gasoline.
Water Capacity,
Fuel-tank Capacity, 20 Gallons.
No. of Speeds, 2 Forward, 1 Reverse.
Low Speed, 2 Miles per Hour.
High Speed, 2¾ Miles per Hour.
Belt Pulley Diameter, 16 Inches.
Belt Pulley Width, 7 Inches.
Bearings, Roller throughout Gear.
Drive Wheel, see Remarks.
Drive Wheel Width, see Remarks.
Front Wheel Diameter, 42 Ins.
Front Wheel Width, 6 Inches.
Wheel Base, 7 Feet.
Width of Machine, 7 Ft. 3½ Ins.
Length of Machine, 11 Feet.
Height of Machine, 6 Feet.
R.P.M. Engine Shaft, 800.
Shipping Weight, 4200 Pounds.
Circle Machine can Turn in, 15-Foot Circle.

Remarks: Endless Drive Track, 48 Inches Long, 16 Inches Wide.

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CHAPTER XII.

MISCELLANEOUS RULES AND FORMULÆ.

A Collection of Useful Rules, Tables and Formulæ That Will Prove of Value to the Student, Mechanic or Farmer, These Include Additional Rules for Figuring Horse-power. for Estimating the Capacity of Tanks, Strength of Materials, U. S. and Foreign Conversion Tables and Other Interesting Information of a Miscellaneous Nature.

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USEFUL RULES, TABLES AND FORMULÆ

RULES FOR CALCULATING HORSE-POWER.

To calculate the horse-power of any 4-cycle motor, the following general formula is always used, this giving the output of a single cylinder and must be multiplied by the number of cylinders for multiple cylinder engines.

$$\frac{PLAR}{33000x2} = \text{H. P.}$$

In which

P=pounds per square inch.
L=length of stroke in feet.
A=piston area in inches.
R=the number of revolutions per minute.

The pressure in any engine is assumed to be a mean effective pressure or average pressure throughout the stroke, and is written M. E. P. For gasoline engines of the usual 4-cycle automobile type this pressure can be assumed at between 75 and 100 pounds, it, of course, varying with the general design. The actual M. E. P. of an engine which has already been built can be determined by the manograph, which records by means of a streak of light the outline of the indicator card, which, if desired, can be permanently retained by means of a photographic plate. It can also be determined at speeds under 500 R. P. M. by diagrams produced by ordinary steam engine indicators, but these are not accurate when used with high speed gasoline engines, the manograph being far superior.

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FORMULA FOR INDICATED HORSE-POWER.

$\frac{D^2 \times L \times n \times M.E.P. \times R.}{550{,}000}$ = I. H. P. 4-cycle × Constant for 2-cycle engines, 275,000.

D^2 = Bore of cylinders in inches squared.
L = Stroke of piston in inches.
R = Revolutions per minute of crankshaft.
n = Number of cylinders.
M. E. P. = Mean effective pressure.

Mean Effective Pressure increases as the compression and decreases as the R. P. M. augment. The thermal efficiency of a motor is the ratio between the work done and the thermal energy contained in the fuel consumed and is between 15 to 30 per cent. The mechanical efficiency, by which is understood the ratio between the work actually done to the energy expended on the piston by the expanding gases, is approximately 85 per cent.

MEAN EFFECTIVE PRESSURES OF TYPICAL AUTO MOTORS.

Make.	Cylinders.	H. P.	R. P. M.	M. E. P.
National...	Four 5x5 11/16"	64	1,400	81.1
		54	1,055	90.9
Pierce.....	Six 4x4¾"	44.5	1,263	76.1
		30.9	800	85.4
Rambler...	Four 5x5½"	43.5	1,091	73.1
Thomas...	Six 4¼x5½"	49	1,091	76.0
Thomas...	Six 4¼x5½"	34	700	83.4

S. A. E. HORSE-POWER FORMULA.

The formula adopted is $\frac{D^2 \times N}{2.5}$ and based on 1,000 feet per minute piston speed. D is the cylinder bore, N the number of cylinders, and 2.5 a constant, based on the average view of the Mechanical Branch as to a fair conservative rating.

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TABLE OF HORSE-POWER FOR USUAL SIZES OF MOTORS, BASED ON S. A. E. FORMULA.

Bore.		Horse-power.			
Inches.	M/M	1 Cyl.	2 Cyls.	4 Cyls.	6 Cyls.
2½	64	2½	5	10	15
2⅝	68	2¾	5½	11	16½
2¾	70	3	6	12 1/10	18 1/5
2⅞	73	3 5/16	6⅝	13¼	19⅞
3	76	3 3/5	7 1/5	14 2/5	21 3/5
3⅛	79	3 15/16	7 13/16	15⅝	23 7/16
3¼	83	4¼	8½	16 9/10	25 2/5
3⅜	85	4 9/16	9⅛	18¼	27 2/5
3½	89	4 9/10	9 4/5	19 3/8	29 2/5
3⅝	92	5¼	10½	20¼	31 3/5
3¾	95	5⅝	11¼	22½	33¾
3⅞	99	6	12	24	36 1/16
4	102	6 2/5	12 4/5	25 3/5	38 2/5
4⅛	105	6 13/16	13⅝	27¼	40 9/10
4¼	108	7¼	14½	28 9/10	43 4/5
4⅜	111	7⅝	15 5/16	30⅝	45 15/16
4½	114	8 1/10	16 1/5	32 2/5	48 3/5
4⅝	118	8 9/16	17⅛	34¼	51 3/5
4¾	121	9	18	36 1/10	54 1/10
4⅞	124	9½	19	38	57
5	127	10	20	40	60
5⅛	130	10½	21	42	63
5¼	133	11	22	44 1/10	66 1/5
5⅜	137	11 9/16	23	46	69 1/10

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Bore.		Horse-power.			
Inches.	M/M	1 Cyl.	2 Cyls.	4 Cyls.	6 Cyls.
5½	140	12¹/₁₀	24¹/₅	48²/₅	72³/₅
5⅝	143	12⅝	25⁵/₁₆	50⅝	75¹⁵/₁₆
5¾	146	13¼	26½	53	79½
5⅞	149	13¹³/₁₆	27⅝	55¼	82⁹/₁₀
6	152	14²/₅	28⁴/₅	57³/₅	86²/₅

To simplify reading of the above, the horse-power figures are approximate, but correct within one-sixteenth.

A SIMPLE HORSE-POWER FORMULA.

H. P. = PLD²R with three decimal places pointed off.

In which P = Mean effective pressure.
L = Stroke in inches.
D = Diameter in inches.
R = Number of cylinders.

The M. E. P. can be assumed or taken from tables. A speed of 1,000 R. P. M. is the only assumption made, and the formula takes into consideration pressure, bore and stroke, and is the simplest form to which the writer has yet been able to reduce the H. P. formula, still retaining all the essentials.

WELL-KNOWN CLUB AND ASSOCIATION HORSE-POWER FORMULAE.

For easy comparison of one car with another and for facilitating handicapping at hill climbs and race meets, the following formulae have been given out by clubs and associations. For the sake of uniformity, let:

D² = Square of piston diameter in inches.
L = Stroke in inches.
R = Revolutions per minute.
N = Number of cylinders.

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HORSE-POWER FORMULA, 4-CYCLE ENGINES.

$$\text{A. L. A. M. Formula, H. P.} = \frac{D^2N}{2.5}$$

$$\text{Roberts Formula, H. P.} = \frac{D^2LNR}{18{,}000}$$

$$\text{Royal Auto Club, H. P.} = \frac{(D+L)^2N}{9.92}$$

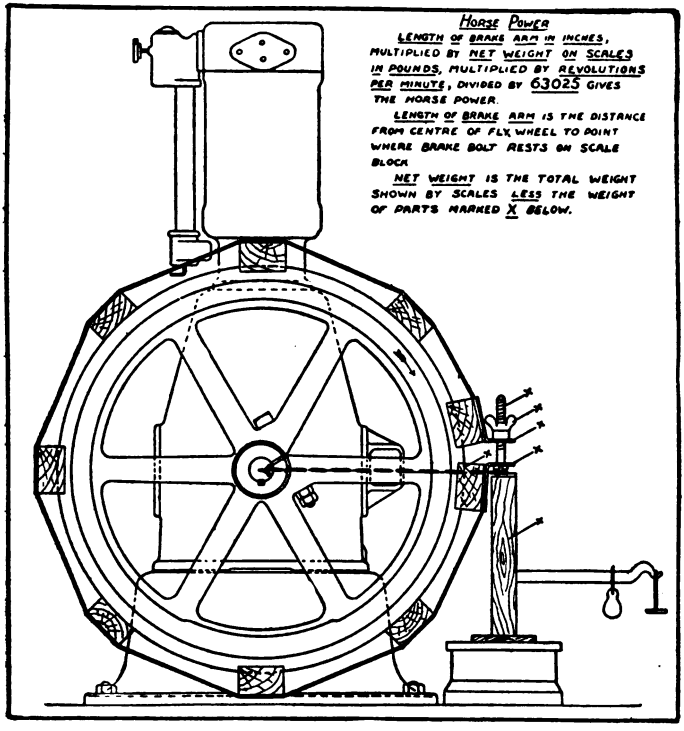
HORSE POWER
LENGTH OF BRAKE ARM IN INCHES, MULTIPLIED BY NET WEIGHT ON SCALES IN POUNDS, MULTIPLIED BY REVOLUTIONS PER MINUTE, DIVIDED BY 63025 GIVES THE HORSE POWER.
LENGTH OF BRAKE ARM IS THE DISTANCE FROM CENTRE OF FLY WHEEL TO POINT WHERE BRAKE BOLT RESTS ON SCALE BLOCK.
NET WEIGHT IS THE TOTAL WEIGHT SHOWN BY SCALES LESS THE WEIGHT OF PARTS MARKED X BELOW.

FIG. 225.—Plan of Easily Constructed Prony Brake for Making Power Tests.

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TABLE FOR CALCULATING B. H. P. OF AN ENGINE.

KNOWING THE BRAKE ARM LENGTH, SPEED AND PULL ON THE SCALES. (C. T. SWART.)

$$\text{B. H. P.} = \frac{2 \times 3.1416 \times R \times P \times N}{33{,}000}$$

R = Brake arm in feet.
P = Pull on scales in pounds.
N = Revolutions per minute.

$$\text{Values in table} = \frac{2 \times 3.1416 \times 100 \times R \times P}{33{,}000}$$

The figures in this table are for a speed of 100 revolutions per minute; therefore when readings are taken for any other speed, the answer found in the table must be multiplied by the actual speed divided by 100.

Pull in Pounds	Arm in Feet.								
	1	1¼	1½	1¾	2	2¼	2½	2¾	3
5	0.095	0.119	0.142	0.166	0.190	0.214	0.238	0.261	0.285
10	0.190	0.238	0.285	0.332	0.381	0.428	0.475	0.522	0.570
15	0.285	0.357	0.428	0.498	0.570	0.642	0.713	0.783	0.785
20	0.380	0.476	0.570	0.666	0.760	0.856	0.950	0.14	1.15
25	0.475	0.595	0.713	0.830	0.950	1.07	1.19	1.31	1.43
30	0.570	0.713	0.885	0.996	1.15	1.28	1.43	1.57	1.71
35	0.665	0.833	1.00	1.16	1.33	1.49	1.66	1.83	2.00
40	0.760	0.952	1.14	1.33	1.52	1.71	1.91	2.09	2.28
45	0.855	1.07	1.28	1.49	1.71	1.93	2.14	2.35	2.56
50	0.950	1.19	1.43	1.66	1.90	2.14	2.38	2.61	2.85
55	1.05	1.31	1.57	1.83	2.09	2.35	2.61	2.87	3.14
60	1.15	1.43	1.71	2.00	2.28	2.57	2.85	3.13	3.42

Table concluded on next page.

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Pull in Pounds	Arm in Feet.								
	1	1¼	1½	1¾	2	2¼	2½	2¾	3
65	1.24	1.55	1.85	2.16	2.47	2.78	3.09	3.39	3.71
70	1.33	1.66	2.00	2.33	2.66	3.00	3.33	3.66	4.00
75	1.43	1.78	2.14	2.49	2.85	3.21	3.57	3.92	4.27
80	1.52	1.90	2.28	2.66	3.04	3.42	3.80	4.18	4.56
85	1.62	2.02	2.42	2.83	3.23	3.64	4.04	4.44	4.85
90	1.71	2.14	2.56	2.99	3.42	3.85	4.28	4.70	5.14
95	1.81	2.26	2.71	3.16	3.61	4.06	4.52	4.96	5.42
100	1.90	2.38	2.85	3.32	3.80	4.27	4.75	5.22	5.71
105	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00
110	2.10	2.62	3.14	3.65	4.18	4.70	5.23	5.75	6.27
115	2.19	2.74	3.28	3.82	4.37	4.92	5.47	6.01	6.66
120	2.28	2.86	3.42	3.98	4.56	5.14	5.71	6.27	6.85

ANTI-FREEZING SOLUTIONS FOR COOLING SYSTEM.

There are three principal agents used as the basis for anti-freezing solutions in the cooling systems of water-cooled tractor engines—calcium chloride, glycerine and alcohol. The alcohol solution is usually preferred, especially since the tariff has been removed on denatured alcohol, because it does not damage the metal of the water jackets, radiator or connections, and has no fault except that it evaporates. The other solutions each have advantages, and users may consult their own preferences as to which agency they prefer.

Calcium chloride ($CaCl_2$) is a very effective cooling agent but unless the chemically pure article is used there is danger of corrosion of the metal with which it comes in contact. A solution of 5 pounds of calcium chloride to each gallon of water will not freeze at any temperature above 35 degrees below zero. A more convenient way to prepare the solution is to first make

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a "saturated solution" of the calcium chloride and water, that is mix with a quantity of water warmed to 60 deg. Fahr. all the calcium chloride the water will completely dissolve, and use equal parts of this saturated solution and pure water in the cooling system of the motor. If chemically pure calcium chloride is used no trouble will result. Chloride of lime ($CaOCl_2$) should be avoided.

Crude calcium chloride retails at about 8 cents or 10 cents a pound, while the chemically pure article is worth about 25 cents in small quantities.

Glycerine is an effective cooling agent and as it will not crystalize in the water jacket it is preferable in this respect to calcium chloride and it has the further merit of not requiring any renewal during the season as it does not evaporate. It is therefore only necessary to add pure water to replace that which has evaporated. The main fault ascribed to glycerine is its tendency to soften hose connections. Equal parts of glycerine and water are used.

In using a glycerine solution care should be taken to thoroughly cleanse the jackets of any residue of crystals from calcium solutions previously used as this residue will thicken and cloud the glycerine solution.

Alcohol can be used in either small or large quantities. The freezing point of various ethyl alcohol mixtures taken from "Physikalisch-Chemische Tabellen" are as follows:

Percentage of alcohol in water..	2.418	5.014	8.105	17.96
Freezing temperature, deg. F...	30.264	28.418	26.213	18.52
Percentage of alcohol in water..	36.43	51.06	86.22	.....
Freezing temperature, deg. F...	3.20	—10.48	—29.02	.....

In addition to these straight mixtures of water and one anti-freezing element there are several combina-

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tions of three or more elements such as 1-5 alcohol, 1-5 glycerine and 3-5 water; 4 parts water, 3 parts carbonate potash and 2 parts glycerine, etc.

A saturated solution of common salt can also be used. It does not affect the metal of the system and remains fluid down to 0 deg. Fahr. An incrustation, however, occurs as the water evaporates. Water must be added to make up for evaporation when glycerine, calcium chloride or salt is used.

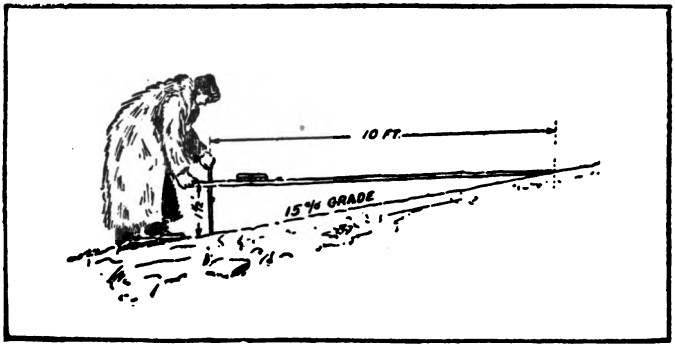

FIG. 226.—A Simple Method of Determining Grade Percentages Without a Gradometer.

HOW TO ASCERTAIN THE GRADE WITHOUT A GRADOMETER.

A method of determining the percentage of a grade on any road without any special instruments is here given and illustrated. All that is required is to measure off ten feet on any convenient stick and rest one end as shown in the sketch above, upon the surface of the road, being careful to keep the stick horizontal. This can be done by using a spirit level or an ordinary bottle filled with water allowing a bubble in the well-known manner. Measure from the end of the stick to the road

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surface and multiply by 10, which will give the per cent of the grade. The average of several such measurements will give fairly accurate results.

TO REMOVE RUST.

Rust may be removed from iron by immersing the piece for several days, or until the rust has entirely disappeared, in water to which a little sulphuric acid has been added with a piece of zinc firmly attached to the iron so that it makes a good contact. The iron is not attacked as long as the zinc remains in contact with it.

Iron or steel may be cleaned of rust by the use of the following: 100 parts stannic chloride dissolved in 1,000 parts water. Add to a solution containing 2 parts tartaric acid dissolved in 1,000 parts water. Add to the mixture 20 cubic centimeters indigo solution diluted with 2,000 parts of water. Clean the metal parts of all grease, apply the solution to the stained portions for a few seconds, rub clean with a moist cloth, then with a dry cloth, and if desired then use any good metal polish. Old rust may be removed in some cases by rubbing with a paste consisting of equal parts of fine tripoli and flowers of sulphur thoroughly mixed with olive oil.

Powdered alum in strong vinegar, oil of tartar, or fine emery is also used to remove rust. Kerosene or turpentine if left on the stained or rusted portions over night, will sufficiently soften the rust so that it may be removed by the use of fine emery cloth followed by a polishing powder.

Rust spots on nickel can be treated with grease, and after several days rubbed with a rag saturated with a few drops of hydrochloric acid in ammonia. Parts should be thoroughly rinsed, dried and polished.

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RUST PREVENTIVE.

The following is a good rust preventive for steel: 16 parts turpentine, and 1 part caoutchouc dissolved by a gentle heat. To this add 8 parts boiled oil, stir and at the same time bring to the boiling point. Apply with a brush after the manner of varnishing. This coating can be removed by the use of turpentine if desired.

TABLE OF COMPOSITION OF COMMON ALLOYS.

	Copper.	Tin.	Zinc.	Lead.	Antimony.	Bismuth.
White Bearing Metal	2	86	27	2	1	..
Bronze	90	2	5	2	..	..
Bronze for bushings	130	16	1	..	..	..
Bearing Bronze (for motors)	110	13	1	..	..	..
Phosphor Bronze (for gears)	*90	10*	..	..	..	..
Bronze for flanges, etc., to be brazed	32	..	1	1	..	..
Babbitt metal	2	50	..	..	4	..
Brass for light parts	2	..	1	..	..	..

* Phosphor tin.

MELTING POINTS OF VARIOUS METALS.

	Degrees F.
Aluminum	1,157
Bronze	1,692
Cast Iron (Gray)	2,012 to 2,228
Cast Iron (White)	1,922 to 2,075
Copper	1,929 to 1,996
Lead	608 to 618
Steel	2,372 to 2,532
Tin	442 to 446
Wrought Iron	2,732 to 2,912

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ROAD SIGNS.

American Motor League "Caution Signs." Background and posts white, symbols black.

No. 1 indicates approach to a steep descent; No. 2, approach to a railroad crossing; No. 3, approach to a branch road (to right); No. 4, approach to a branch road (to left); No. 5, approach to cross roads; No. 6, approach to a ditch or abrupt depression in the road; No. 7, approach to a hummock or "thank you, ma'am;" No. 8, approach to a city, village or other collection of inhabited dwellings; No. 9, is a general caution signal indicating the proximity of any danger or obstruction not scheduled above, or any other condition requiring caution. No. 9 (not shown in cut) is a plain white sign and can be improvised in emergency cases by using a sheet of white cloth fastened upon a board of proper shape. Each sign is placed at a distance of not less than 200, nor more than 300 yards from the point to which it refers.

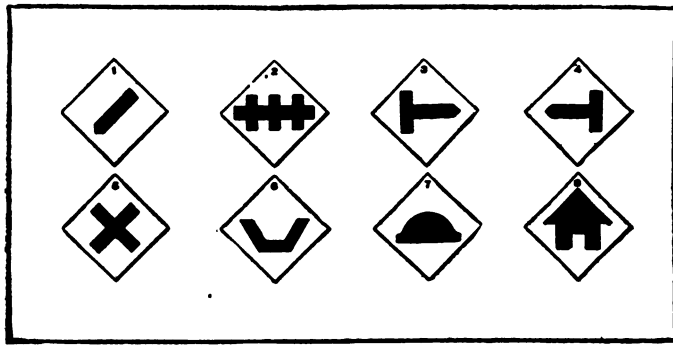

FIG. 227.—Road Signs of American Motor League That Give Warnings of Interest to Tractor Operators or Motorists.

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TABLE OF HORSE-POWER COSTS.

Motive Power	Rate of Fuel Consumption.	Cost of Fuel per Brake Test Horse-power 1 Hour. Cost of Coal per 2,000 Pounds.				
Gas Engine on Producer Gas.	In pounds per H.P. Hour.	$3.00	$4.00	$5.00	$6.00	$7.00
	.8	.0012	.0016	.0020	.0024	.0028
	1.00	.0015	.0020	.0025	.0030	.0035
	1.25	.0019	.0025	.0031	.0037	.0044
	1.50	.0023	.0030	.0037	.0044	.0053

Gas Engine on Natural Gas.	In Cubic Feet per H.P. Hour.	Cost of Natural Gas, 1,000 Cubic Feet.				
		$0.15	$0.20	$0.25	$0.30	
	9	.0014	.0018	.0023	.0027	
	10	.0015	.0020	.0025	.0030	
	11	.0017	.0022	.0028	.0033	
	12	0018	.0024	.0030	.0036	

Gas Engine on Illuminating Gas.	In Cubic Feet per H.P. Hour.	Cost of Gas per 1,000 Cubic Feet.				
		$0.60	$0.70	$0.80	$0.90	$1.00
	15	.0090	.0105	.0120	.0135	.0150
	17	.0102	.0119	.0136	.0153	.0170
	20	.0120	.0140	.0160	.0180	.0200

Gasoline Engine	In Pints per Brake H.P. Hour.	Cost of Gasoline per Gallon.				
		$0.10	$0.12	$0.14	$0.16	$0.18
	0.80	.0100	.0120	.0140	.0160	.0180
	1.00	.0125	.0150	.0175	.0200	.0225
	1.10	.0137	.0165	.0192	.0220	.0247

Table concluded on next page.

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TABLE OF HORSE-POWER COSTS—Continued.

Electric Motor 85% Efficiency of Wiring.	In Kilowatts per H.P. Hour	Cost of Electricity per Kilowatt Hour.				
		$0.02	$0.03	$0.04	$0.05	$0.07
	0.878	.0175	.0263	.0351	.0439	.0614

Steam Engine on Coal.	In Pounds per H.P. Hour.	Cost of Coal per 2,000 Pounds.				
		$3.00	$4.00	$5.00	$6.00	$7.00
	4	.0060	.0080	.0100	.0120	.0140
	6	.0090	.0120	.0150	.0180	.0210
	8	.0120	.0160	.0200	.0240	.0280
	10	.0150	.0200	.0250	.0300	.0350

CAPACITY OF CYLINDERS.

NUMBER OF GALLONS FOR ONE FOOT DEPTH.

When diameter is given in feet = (square of diameter)x5.873
When diameter is given in inches = (square of diameter)x0.0408

TABLE OF CAPACITIES OF CYLINDRICAL TANKS IN LIQUID GALLONS (APPROXIMATE).

1	2	3	4	5	6	7	8	9	10	Gallons	Gals. per inch
6x12	6x18	6x24	6x36	6x42						6″ dia.	.122
	7x12	7x18	7x24	7x30	7x36	7x42	7x48			7″ "	.165
		8x15	8x18	8x24	8x30	8x36	8x42	8x45	8x48	8″ "	.217
		9x12	9x15	9x18	9x24	9x30	9x34	9x36	9x40	9″ "	.275
					10x20	10x24	10x26	10x28	10x32	10″ "	.340
						12x16	12x18	12x20	12x24	12″ "	.486

10	15	20	25	30	35	40	45	50	Gallons	Gals. per inch
10x32	10x48								10″ dia.	.340
12x24	12x34	12x42	12x50	12x60					12″ "	.486
14x18	14x24	14x30	14x38	14x44	14x52	14x60			14″ "	.666
	16x18	16x24	16x30	16x36	16x42	16x48	16x54	16x60	16″ "	.870

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RULE FOR CAPACITY OF SQUARE OR RECTANGULAR TANKS.

Multiply height in inches by width in inches and the product by length in inches, then divide by 231, which will give answer in gallons. For small tanks, divide by 57.75, and you will obtain capacity in quarts.

TRACTIVE EFFORT ON VARIOUS SURFACES.

	Pounds per Ton.
On rails or plates	5.16
Asphalt or hardwood	12.24
Macadam	30.60
Loose gravel	140 to 200
Sand	400.

REVOLUTIONS OF WHEELS OF VARYING DIAMETER PER MILE.

Dia. in Inches.	Circum. in Feet.	Revolutions per Mile.	For R.P.M. multiply Miles per Hour by	For R.P.S. multiply Miles per Hour by
48	12.57	420.0	7.00	0.1166
50	13.00	403.4	6.72	0.1120
52	13.61	387.9	6.46	0.1073
54	14.14	373.4	6.22	0.1033
56	14.66	360.2	6.00	0.1000
58	15.18	347.8	5.79	0.0965
60	15.71	336.1	5.60	0.0933
62	16.23	325.3	5.42	0.0903
64	16.75	315.2	5.25	0.0875
66	17.28	305.5	5.09	0.0848
68	17.80	296.6	4.94	0.0823
70	18.36	288.1	4.80	0.0798
72	18.85	280.1	4.67	0.0778
78	20.42	258.6	4.31	0.0718
84	21.99	240.1	4.00	0.0666
90	23.56	224.1	3.73	0.0622
96	25.16	210.1	3.50	0.0586

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STRENGTH OF AUTOMOBILE STEELS.

SUMMARY OF TENSILE TESTS

MADE WITH 2-INCH TEST SPECIMENS OF CARPENTER STEEL COMPANY'S AUTO STEELS IN ACCORDANCE WITH THE STANDARD SPECIFICATIONS OF THE AMERICAN SOCIETY FOR TESTING MATERIALS.

Grade.	Elastic Limit in Pounds per Square Inch.	Tensile Strength in Pounds per Square Inch.	Elongation in Two Inches.	Reduction of Area.	Condition.
			%	%	
Chrome-Nickel Auto-Steel No. 5-317	65,650	91,200	27.0	64.3	Natural
" " "	210,000	315,000	5.0	19.0	Tempered
" " "	185,400	269,200	6.0	20.2	"
" " "	140,000	225,200	8.0	30.2	"
" " "	114,000	130,500	19.0	60.0	Toughened
Chrome-Nickel Auto-Steel No. 3-317	70,000	106,000	18.0	45.0	Natural
" " "	135,000	197,000	9.0	37.0	Tempered
" " "	90,000	110,000	25.0	55.0	Toughened
Dynamic Auto-Steel No. L3-14	103,800	121,390	20.0	60.0	"
Special Nickel Steel No. 575	80,000	99,000	21.0	58.2	"
" " No. 575	87,000	102,000	21.0	62.0	"
Crucible Auto-Steel No. L-521	160,000	175,000	7.0	30.0	Tempered
Special Auto-Steel No. 506	70,000	113,950	22.0	49.0	Natural
" " No. 506	71,200	105,600	24.0	49.3	"
Weldable Auto-Steel No. 492	49,050	93,000	21.5	35.0	"
" " No. 492	50,000	93,000	22.0	37.0	"
Auto-Steel No. 478	48,300	74,500	29.0	43.0	"
" No. 478	46,500	77,500	28.0	45.0	"

No. 5-317. Suitable for transmission gears, counter-shafts and parts used for transmission of power.

No. 3-317. Mild-temper suitable for case hardened gears.

No. L 3-14. Axle-steel, to withstand alternating stresses and dynamic strains.

No. 575. Contains 3½ per cent. nickel and is manufactured to meet the U. S. Navy specification known as "High Grade."

No. L-521. Crucible gear-steel (moderate price) gears can be tempered and do not require hardening.

No. 506. Manganese steel for shafts, bolts, etc., not subjected to excessive alternating or recurrent stresses.

No. 492. Special straight-carbon crucible steel, with a

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fairly high tensile strength, suitable for axles and other parts that have to be welded.

No. 478. Special high-grade open-hearth steel, which is particularly adapted to such parts as are not subjected to unusual strains. It is suitable for axles, axle-journals, and various small parts of automobiles.

USEFUL CONVERSION TABLES AND RULES.

TO CHANGE COMMON FRACTIONS INTO A DECIMAL

To convert a common fraction into a decimal: Divide the numerator by the denominator, adding to the numerator as many ciphers prefixed by a decimal point as are necessary to give the number of decimal places desired in the result.

$$\frac{2}{3} = 2.0000 \div 3 = 0.6666 +$$

DECIMAL EQUIVALENTS OF FRACTION OF ONE INCH.

ADVANCING BY 64TH.

1–64	0.015625	17–64	0.265625	33–64	0.515625	49–64	0.765625
1–32	0.03125	9–32	0.28125	17–32	0.53125	25–32	0.78125
3–64	0.046875	19–64	0.296875	35–64	0.546875	51–64	0.796875
1–16	0.0625	5–16	0.3125	9–16	0.5625	13–16	0.8125
5–64	0.078125	21–64	0.328125	37–64	0.578125	53–64	0.828125
3–32	0.09375	11–32	0.34375	19–32	0.59375	27–32	0.84375
7–64	0.109375	23–64	0.359375	39–64	0.609375	55–64	0.859375
1– 8	0.125	3– 8	0.375	5– 8	0.625	7– 8	0.875
9–64	0.140625	25–64	0.390625	41–64	0.640625	57–64	0.890625
5–32	0.15625	13–32	0.40625	21–32	0.65625	29–32	0.90625
11–64	0.171875	27–64	0.421875	43–64	0.671875	59–64	0.921875
3–16	0.1875	7–16	0.4375	11–16	0.6875	15–16	0.9375
13–64	0.203125	29–64	0.453125	45–64	0.703125	61–64	0.953125
7–32	0.21875	15–32	0.46875	23–32	0.71875	31–32	0.96875
15–64	0.234375	31–64	0.484375	47–64	0.734375	63–64	0.984375
1– 4	0.25	1– 2	0.50	3– 4	0.75	1	1.

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MONEY CONVERSION TABLES.

English.	U. S.
1 Farthing	$0.0051
1 Farthing	$0.0051
1 Penny	.0203
6 Pence	0.1217
1 Shilling	0.2433
20 Shillings	4.8665
1 Pound	4.8665
5 Pounds	24.3325

U. S.	English.
$0.01	1.96 Farthings
$0.01	1.96 Farthings
0.01	0.492 Pence
0.25	12.3 "
0.25	1.0275 Shillings
1.00	4.11 "
1.00	0.2055 Pounds
5.00	1.0275 "

French.	U. S.
1 Centime	$0.00193
10 Centimes	0.0193
100 "	0.193
1 Franc	0.193
10 Francs	1.93

U. S.	French.
$0.01	5.1813 Centimes
0.10	51.813 "
1.00	5.1813 Francs
10.00	51.813 "

German	U. S.
1 Pfennig	$0.00238
25 Pfennigs	0.0595
100 "	0.238
1 Mark	0.238
10 Marks	2.38

U. S.	German.
$0.01	4.201 Pfennigs
0.25	1.05025 Marks
1.00	4.201 "
10.00	42.01 "

THERMOMETER SCALE CONVERSIONS.

One Fahrenheit degree = 5-9 degree Centigrade = 4-9 degree Réaumur. In the following conversion formulae:

F = Degrees Fahrenheit.
C = Degrees Centigrade.
R = Degrees Réaumur.

Readings above freezing point, 32 degrees F., zero C., zero R., are positive (+), readings below are treated as negative (—).

$$F = \frac{9C}{5} + 32;\ F = \frac{9R}{4} + 32;\ C = \frac{5(F-32)}{9};\ R = \frac{4(F-32)}{9}$$

Freezing point F = 32 degrees = zero C = zero R.
Boiling point = 212 degrees F = 100 degrees C = 80 degrees R.

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METRIC CONVERSION TABLES.

U. S. TO METRIC.	METRIC TO U. S.

LINEAR.

1 inch = 25.4001 millimeters.	1 meter = 39.3700 inches.
1 foot = 0.304801 meters.	1 meter = 3.28083 feet.
1 yard = 0.914402 meters.	1 meter = 1.09361 yards.
1 mile = 1.60935 kilometers.	1 kilometer = 0.62137 miles.

SQUARE.

1 square inch = 6.452 square centimeters.
1 square foot = 9.290 square decimeters.
1 square yard = 0.836 square meters.
1 square centimeter = 0.1550 square inches.
1 square meter = 10.7640 square feet.
1 square meter = 1.196 square yards.

CUBIC.

1 cubic inch = 16.387 cubic centimeters.
1 cubic foot = 0.02832 cubic meters.
1 cubic yard = 0.765 cubic meters.
1 cubic centimeter = 0.0610 cubic inches.
1 cubic meter = 35.314 cubic feet.
1 cubic meter = 1.308 cubic yards.

WEIGHT.

1 grain = 64.7989 milligrammes.
1 avoirdupois ounce = 28.3495 grammes.
1 troy ounce = 31.10348 grammes.
1 avoirdupois pound = 0.45359 kilogrammes.
1 milligramme = 0.01543 grains.
1 kilogramme = 15432.36 grains.
1 hectogramme = 3.5274 avoirdupois ounces.
1 kilogramme = 2.20462 avoirdupois pounds.

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METRIC CONVERSION TABLES—Continued.

CAPACITY.

1 fluid drachm = 3.70 cubic centimeters.
1 fluid ounce = 29.57 milliliters.
1 quart = 0.94636 liters.
1 gallon = 3.78544 liters.
1 milliliter = 0.27 fluid drachms.
1 centiliter = 0.338 fluid ounces.
1 liter = 1.0567 quarts.
1 dekaliter = 2.6417 gallons.

USEFUL INFORMATION.

HORSE-POWER OF SHAFTS FOR GIVEN DIAMETER AND SPEED.

Diameter of Shaft Inches.	Revolutions per Minute.									
	100	125	150	175	200	225	250	300	350	400
1 3/16	2.4	3.0	3.6	4.2	4.8	5.4	6.0	7.2	8.4	9.6
1 7/16	4.3	5.4	6.5	7.6	8.6	9.8	10.8	13.0	15.2	17.2
1 11/16	6.5	8.0	9.7	11.2	13.0	14.6	16.0	19.4	22.4	26.0
1 15/16	10.0	12.5	15.0	17.5	20.0	22.5	25.0	30.0	35.0	40.0
2 3/16	14.0	17.8	21.0	24.5	28.0	31.5	35.6	42.0	49.0	56.0

RULES FOR DETERMINING THE SPEED OF PULLEYS.

1. To find the number of revolutions of the driven shaft when the diameter of the driving pulley and its speed are given, multiply the diameter of the driving pulley by its number of revolutions per minute, and divide the product by the diameter of the driven pulley; the quotient will be the speed of the driven pulley expressed in revolutions per minute.

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Example: Driving pulley is 24 inches in diameter and makes 125 revolutions per minute. At what rate would a pulley 8 inches in diameter be driven?

$$\frac{24\times125}{8} = 375 \text{ revolutions per minute.}$$

2. To find the diameter of the driven pulley when the diameter and number of revolutions of the driving pulley are given, multiply the diameter of the driving pulley by the number of its revolutions, and divide the product by the number of revolutions the driven pulley is to make.

Example: What would be the diameter of the driven pulley making 375 revolutions per minute, if the driving pulley is 24 inches in diameter and makes 125 revolutions per minute?

$$\frac{24\times125}{375} = 8 \text{ inches in diameter.}$$

3. To find the number of revolutions of the driving pulley when its diameter and the diameter and speed of the driven pulley are given, multiply the diameter of the driven pulley by its revolutions and divide the product by the diameter of the driving pulley; the quotient will be the speed of the driving pulley expressed in revolutions per minute. Example:

$$\frac{8\times375}{24} = 125 \text{ revolutions per minute.}$$

4 To find the diameter of the driving pulley, multiply the diameter of the driven pulley by the number of its revolutions per minute, and divide the product by the number of revolutions of driving shaft; the quotient will be the diameter of the driving pulley required. Example:

$$\frac{8\times375}{125} = 24 \text{ inches in diameter.}$$

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HORSE-POWER BELTING WILL TRANSMIT.

Width of Belt, Inches.	Horse-power per 100 Feet Belt-Speed.	
	Single Belt.	Double Belt.
1	0.09	0.18
2	0.18	0.36
3	0.27	0.55
4	0.36	0.73
5	0.45	0.91
6	0.55	1.09
7	0.64	1.27
8	0.73	1.46
9	0.82	1.64
10	0.91	1.82
11	1.00	2.00
12	1.09	2.18
14	1.27	2.55
16	1.45	2.91
18	1.64	3.27
..	....	....
20	1.82	3.64
22	2.00	4.00
24	2.18	4.36
28	2.55	5.09
32	2.91	5.82
36	3.27	6.55
40	3.64	7.27
..	....	....

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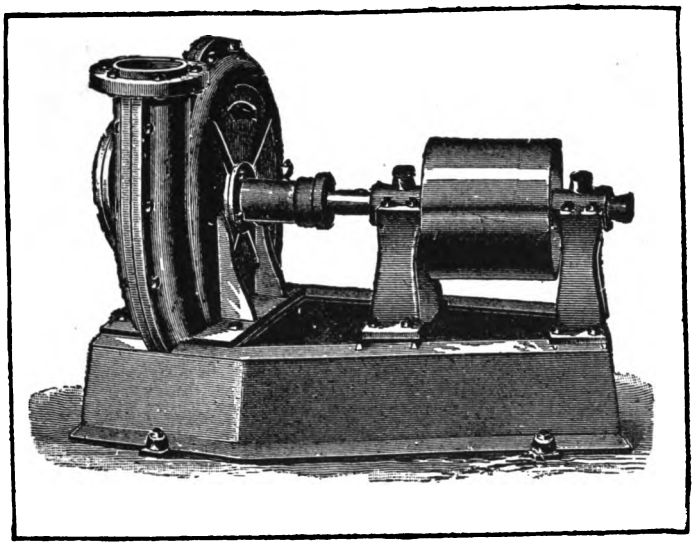

FIG. 228.— Belt Driven Centrifugal Pump Suitable for Irrigation Purposes May be Driven by Direct Connection With Belt Pulley of Gas Tractor Power Plant.

CAPACITY OF CENTRIFUGAL PUMPS AND POWER NEEDED TO OPERATE.

Capacity per Minute, Gallons.	H. P. Required, Foot Lift.	Diam. of Suction Pipe in Ins.	Diam. of Discharge Pipe in Ins.	Weight, Pounds.
75–80	0.032	2	1½	70
80–125	0.04	2	2	120
125–160	0.05	2½	2	190
160–250	0.085	3	2½	230
250–350	0.126	4	3	250
350–400	0.190	5	3½	375
400–600	0.270	5	4	450
600–900	0.420	6	5	500
900–1,800	0.525	8	6	750
1,800–3,000	1.35	10	8	1,200
3,000–4,000	1.80	12	10	1,725
4,000–5,000	2.40	14	12	2,200

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WHAT MAY BE ACCOMPLISHED BY PUMPS OF VARYING CAPACITY IN IRRIGATION WORK.

Acres Irrigated in 10 Hours.

Gallons Pumped per Minute.	1-in. deep.	2-in. deep.	3-in. deep.	4-in. deep.	5-in. deep.	6-in. deep.
600	13.2	6.6	4.4	3.3	2.6	2.2
824	18.2	9.1	6.0	4.5	3.6	3.0
944	20.8	10.4	6.9	5.2	4.1	3.4
988	21.8	10.9	7.2	5.4	4.3	3.6
1,000	22.1	11.0	7.3	5.5	4.4	3.7
1,200	26.5	13.2	8.8	6.6	6.3	4.4
1,500	33.1	16.5	11.0	8.2	6.6	5.5
2,000	44.2	22.1	14.7	11.0	8.8	7.3

Acres Irrigated in 24 Hours.

Gallons Pumped per Minute.	1-in. deep.	2-in. deep.	3-in. deep.	4-in. deep.	5-in. deep.	6-in. deep.
600	31.8	15.9	10.6	7.9	6.3	5.3
824	43.7	21.8	14.5	10.9	8.7	7.3
944	50.0	25.0	16.7	12.5	10.0	8.3
988	52.4	26.2	17.4	13.1	10.4	8.7
1,000	53.0	26.5	17.6	13.2	10.6	8.8
1,200	63.6	31.8	21.2	15.9	12.7	10.6
1,500	79.5	39.7	26.5	19.9	15.9	13.2
2,000	106.0	53.0	35.3	20.5	21.2	17.6

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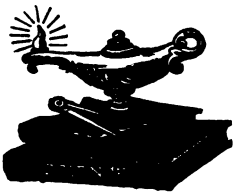

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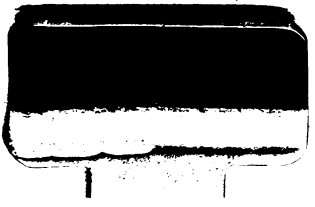

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